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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

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A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

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Initiation Fees		*Annual Dues*	
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New England Water Works Association

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PUMPING WATER — AN HISTORICAL REVIEW.

BY WALTON H. SEARS.*

[*Read March 21, 1935.*]

From the beginnings of civilization, man has been busy lifting water. The early civilizations were for the most part developed in regions of scant rainfall, and employment of labor to water the fields was vast and continual. Today, in our complex civilization with its great factories, wide use of modern plumbing and high water consumption, the pumping of water to great heights in quantities once undreamed of is a commonplace accepted by most people without thought or wonder.

It seems fitting, therefore, that we stop a moment and look back over the years to see how the ancients raised water and to trace the development of the art of pumping from the days of the early Egyptians to the present. That is the purpose of this paper.

First, a word about power. It is, of course, the advance in the generation and application of power that has made possible, directly and indirectly, the pumping achievements of today. Prior to the invention of the steam engine the only mechanical power available was that of falling water and of wind. Swiftly flowing water has been used quite generally since very early days as a source of power, and wind power has long been employed to some extent, but we find the old machines for the most part driven by man or beast and the accompanying illustrations indicate various ways in which this power was applied. Man power has been and still is employed to a remarkable extent in preference to the use of animals in the most populous regions apparently on the economic reasoning that when there are more than enough men to till the available lands, it is better to employ human beings in this capacity than to use oxen, which would require for their support acres of land which are not available.

Bucket Elevators.

The simplest devices for raising water are the bucket and rope and the pole and bucket. From these and from the tipping gutter, shown in Figure 1, appear to have developed the family of machines, classified as bucket eleva-

*Mechanical Engineer, Metropolitan District Water Supply Commission, Boston, Mass.

tors. They include the jantu, sweep, noria, tympanum, chain of pots and chain pump. All of these are of great antiquity but are still to be found in parts of the old world with little if any change from their predecessors centuries ago.

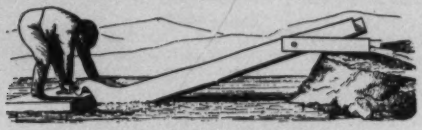

FIG. 1.— TIPPING GUTTER.

FIG. 2.— SWEEPS IN TIERS RAISING WATER FROM THE NILE.

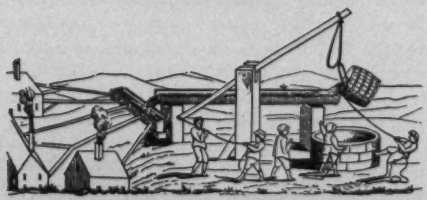

FIG. 3.— SWEEP FOR COMMUNITY SUPPLY.
(from Munster's Cosmography — 1550.)

The Jantu. The jantu is a tipping gutter counterweighted and operated by the feet. It is used in India and other parts of Asia and has been described as consisting of a hollow trough of wood, about 15 ft. long,

6 in. wide, and 10 in. deep, placed on a horizontal beam lying on bamboos fixed in the bank of a pond or river. "One end of the trough rests upon the bank, where a gutter is prepared to carry off the water, and the other end is dipped in the water, by a man standing on a stage, plunging it in with his foot. A long bamboo with a large weight of earth at the farther end of it, is fastened to the end of the jantu near the river, and passing over the gallows before mentioned, poises up the jantu full of water, and causes it to empty itself into the gutter."

It is probable that the jantu was used by the ancient Egyptians and was alluded to by Moses in his description of the land to which he was leading his people when he said: "For the land whither thou goest in to possess it, is not as the land of Egypt from whence ye came out, where thou sowedst thy seed, and *waterest it with thy foot.*"*

The Sweep. From the pole and bucket came the sweep which has probably been more extensively used in all ages and in all nations than any other machine for raising water. Its lift is limited to about 15 ft. so that it is not adapted for use in deep wells. Arranged in series, however, it can be used for raising water to any desired height, and in this way it has been used for centuries along the banks of the Nile where a hundred years ago, it has been said, thirty to fifty tiers were not uncommon (see Figure 2).

This device is pictured in sculptures of the 16th century B.C. at Thebes. It seems to have been used in Persia in the time of Herodotus in the 5th century B.C. Aristotle mentions it as in common use among the Greeks, and that it was familiar to the Romans is attested by the fact that Plutarch in his life of Marcellus writes that Marcellus was wont to say of the occasion when the Roman vessels at the seige of Syracuse were grappled by hooks and elevated in the air by levers that projected over the walls of the city, "Archimedes used his ships to draw water with."

Comparison of the sculptures of Thebes with photographs of sweeps now in use shows no essential change in 3 600 years of use in Egypt, where this machine is called the "shaduf." In Hindustan where its name is the "picotah," it is operated by the walking of a man on the beam. The operator is said to acquire great expertness and moves the bucket up and down with great speed.

Figure 3, from Sebastian Munster's Cosmography of 1550, shows an application of the sweep for supplying water to a town. It is a far cry from present practice.

The Noria. Some time in the dim past somebody conceived the idea of taking a number of sweeps and assembling them as the spokes of a wheel, so that when the wheel was revolved about a horizontal axis the buckets would dip into a stream or lake, fill, rise and discharge near the highest point of travel. Thus was born the noria or Persian Wheel. This machine in various forms has been used for ages in the older civilizations of China, Egypt, Greece, Turkey, Spain and elsewhere and is still to be found,

*Deuteronomy XI, 10.

especially in China. When employed to raise water from swiftly flowing streams, the power of the stream is utilized to drive it by paddles attached to the periphery of the wheel thus converting it into a simple undershot water wheel. Indeed Webster's *New International Dictionary* defines "noria" as "a large water wheel turned by a stream without a fall and

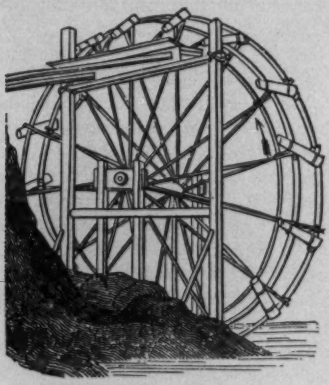

FIG. 4.— CHINESE NORIA.

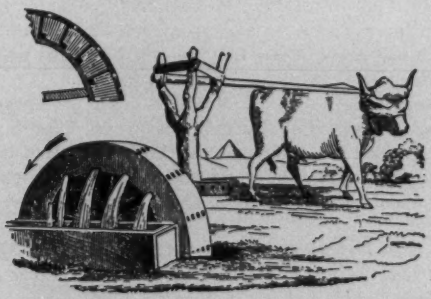

FIG. 5.— AN EGYPTIAN NORIA.

carrying at its circumference buckets which raise water and discharge it into a trough." The fact is, however, that the noria is used extensively, especially in China, with nothing but man power to drive it.

The Chinese make the noria in what would seem to have been its primitive form (see Figure 4) entirely of bamboo without nails, the pieces of bamboo being lashed together. Such wheels are to be found in common use in China

often turned by the walking of men on the top and sometimes by the power of the stream from which the water is lifted. In the August, 1931, number of the *National Geographic Magazine* are excellent photographs of both types which, unfortunately could not be reproduced in this paper owing to copy-

FIG. 6.— EGYPTIAN NORIA WITH EARTHEN POTS.

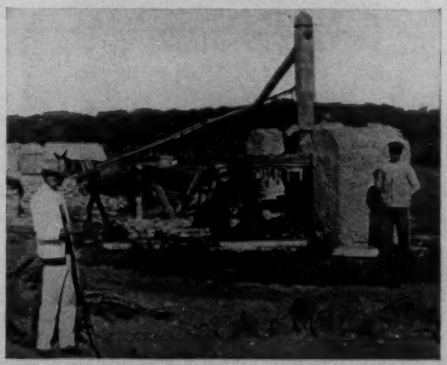

FIG. 7.— SPANISH NORIA WITH EARTHEN POTS.

right agreements. One of them shows an enormous battery of eleven noria wheels on a common shaft raising water from a river which drives them. They are apparently about 40 or 50 ft. in diameter and the combined capacity is probably about that of a 4-in. centrifugal pump.

Vitruvius, a Roman architect and engineer living about the beginning of the Christian era, published a treatise on his professions and included

brief descriptions of hydraulic machines then in use. He describes the noria as constructed by the Romans. He says "Around the extremity of the side of the wheel, square buckets cemented with pitch and wax are fixed; so that when the wheel is turned by the walking of men, the filled buckets being raised to the top, and turning again toward the bottom, discharge of themselves what they have brought into the reservoir."

An interesting type of noria used in Egypt is shown in Figure 5.* Although the sketch does not show flaps acting as valves over the inner

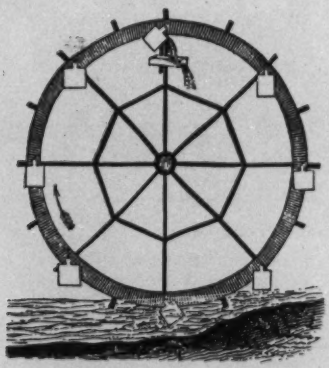

FIG. 8.— NORIA WITH HANGING BUCKETS.

ends of the openings through which the water entered, presumably they were used, else there must have been serious loss of water and it seems probable that advantage would have been taken of such a simple device.

Figures 6 and 7 show the use of earthenware pots or jugs with the noria and also the primitive type of gearing which is commonly used through all the East and which in all probability is identical with that of the early ages. Figure 6 is from Egypt; Figure 7 from Spain.

Wheels with fixed buckets lose much water by spilling after the buckets have been raised nearly to the required elevation. The inefficiency of this arrangement did not escape the notice of the ancients and a type of noria with hanging buckets, shown in Figure 8, was invented. Wheels like this have been used in Europe ever since the days of the Roman Empire and perhaps in earlier days. They have been in wide use in many old world countries and were extensively employed in England in the 17th century. They were probably never used in this country.

The noria was employed by the ancients in connection with public water supplies and the following quotation from Ewbank's book† seems to

*"Grande Description d'Egypt," published in 1817 by the French Army by order of Napoleon.

†"A Descriptive and Historical Account of Hydraulic and Other Machines for Raising Water."—Thomas Ewbank. 12th ed. New York, 1851 (first ed. 1840).

be of worthwhile interest to water works men of 1935. The wheels referred to are of the type just discussed.

Perhaps the most interesting specimens of these machines extant, are to be found in another and very ancient city of Syria; in Hamath on the Orontes, so named after its founder, one of the sons of Canaan. "Two days journey below Homs, (says Volney) is Hamath, celebrated in Syria for its water works. The wheels are the largest in the country, being thirty-two feet in diameter." The city is built on both sides of the river, and is supplied with water from it by means of them, the buckets of which empty themselves into stone aqueducts, supported on lofty arches on a level with the

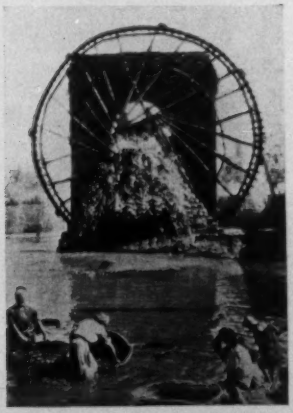

FIG. 9.— ANCIENT NORIA AT HAMA, SYRIA.
(Photograph by Harold Lamb.)

ground on which the city stands. They are propelled by the current. Burckhardt observed about a dozen of them, the largest he says, "is called Naoura el Mahommeyde, and is at least seventy feet." They are, he remarks, the greatest curiosity which a modern traveler can find in the city. Their enormous magnitude will be apparent, if we consider that the loftiest class of buildings in this city, (N. York), those of six stories, seldom exceed sixty feet. If therefore, the largest of the Persian wheels at Hamath, were placed on the pavement, with its side towards a range of such buildings, it would occupy a space nearly equal to the fronts of three of them, and would extend several feet over the roofs of the highest — and twelve of them would occupy a street, one sixth of a mile in length.

The construction of the water works of Hamath have probably remained unaltered in their general design, from very remote times. The peculiar location of this city, the rapidity of the river, (named El Ausi, the swift), and its consequent adaptation to propel undershot wheels, which we know were used in such works by the ancients, render it probable that the present mode of raising water, is much the same as when this city flourished

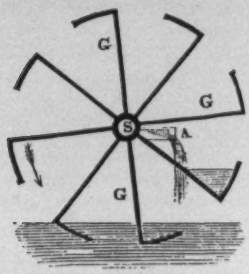

FIG. 10.— TYMPANUM.

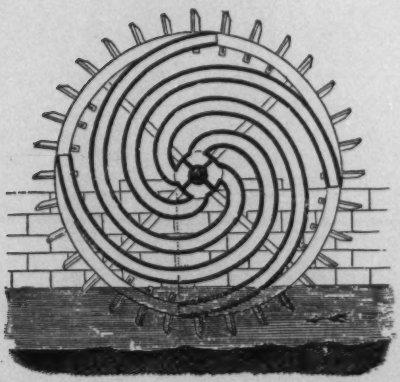

FIG. 11.— DE LAFAYE'S TYMPANUM.

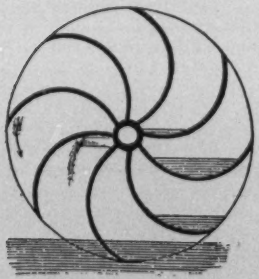

FIG. 12.— SCOOP WHEEL.

under Solomon; and when the Romans under Aurelius, overthrew the Queen of Palmyra and her army, in its immediate vicinity; and from the great antiquity of the noria, its extensive use over all Asia in former ages, and its peculiar adaptation to Hamath, and the tenacious adherence of the orientals to the devices of their forefathers; we infer that the machines which Burckhardt beheld with admiration, raising the water of the Orontes, were similar to others in use at the same city, when the spies of Moses, searched the land, "from the wilderness of Zin unto Rehob, as men come to Hamath."

Fortunately I am able to illustrate, in Figure 9, one of these huge machines, which are still in use. This illustration is taken from the *National Geographic Magazine* of December, 1933, and is reproduced through the courtesy of that periodical and of the photographer, Mr. Harold Lamb.

The Tympanum. Whereas the noria undoubtedly came from the sweep by the application of rotary motion to a series of such devices, the tympanum was similarly derived from the tipping gutter. The principle is illustrated in Figure 10 which is diagrammatic only. Actually the ancient tympanum was constructed of two disks of plank separated by radial partitions of wood, the spaces between them at the circumference being closed except for the openings to admit the water. Where each partition joined the shaft there was a hollow channel in the shaft through which the water was discharged into a trough or gutter immediately under it. From its resemblance in appearance to a large drum it was called "tympanum" by the Romans. This is one of the machines described by Vitruvius, and of it he says, "it does not raise the water high, but it discharges a great quantity in a short time."

In the early part of the 18th century a Frenchman, M. DeLaFaye, member of the Royal Academy of Science of France developed a clever improvement of the tympanum used by the Romans. His invention is illustrated in Figure 11. By the use of passages curved in the form of the involute of the shaft, the water is raised vertically with the center of gravity of the water load always under the edge of the axle, whereas in the Roman tympanum, the water is raised at a considerable distance from the center of rotation. At first glance it would appear that this would result in a considerable saving in power owing to the reduction in the moment arm or leverage of the water being raised. Actually, this is not so. What is accomplished is a speeding up of the wheel with a reduction in the force required to turn it, making it readily adaptable to propulsion as an undershot wheel.

Still another modification of the tympanum, illustrated diagrammatically in Figure 12, has been used in relatively modern times, i.e. during the last century, to drain the marshes of Lincolnshire,England. It is known as the scoop wheel and was driven by a steam engine.

The Chain of Pots. As has been stated, the noria and tympanum undoubtedly developed from the sweep and tipping gutter and are adaptable only to relatively low lifts from open water surfaces. There is also another class of ancient machines used for raising water from wells of rela-

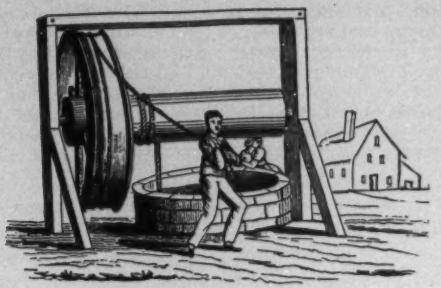

FIG. 13.— WINDLASS WITH ROPE DRUM.

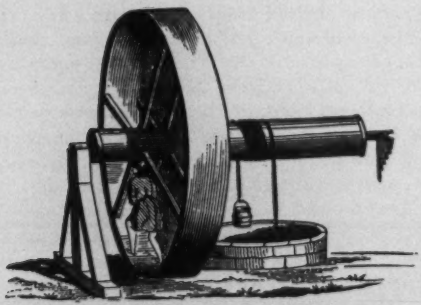

FIG. 14.— WINDLASS WITH TREAD WHEEL.

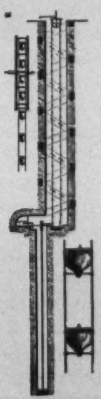

FIG. 15.— JOSEPH'S WELL — CAIRO.

tively great depths. This class is descended from the cord and bucket. There are the single bucket attached to a cord passing over a pulley suspended over the well, the rope being hauled by hand or ox; the pulley with cord having a bucket at each end resulting in a saving of time and some energy as compared with the single bucket; various types of windlass for raising and lowering a bucket; and the chain of pots, the parent of the chain pump of later days.

Space is not available to show here more than a few of these devices of which many have been described and recorded in ancient literature. Some

FIG. 16.— EGYPTIAN CHAIN OF POTS.

are simple, some complicated and probably impractical, but all indicate that ingenuity and a knowledge of fundamental mechanics were possessed by the human race long before our time.

Figures 13 and 14 show unique methods of raising water by windlass. Of the rope-driven drum the *Dictionarium Rusticum*, published in London in 1704, says, "There cannot be a more expeditious way to raise water from a deep well." The use of the tread wheel shown in Figure 14 is very ancient, and its application to raising water from wells is probably incidental though it may have been the reason for its original invention. Its origin is believed to be Chinese. Not only were men used to drive tread wheels but various animals; even bears were so trained by the Goths.

From the pulley and cord with bucket at each end, it was natural to proceed a step farther and connect the two ends of the cord and attach to it a series of buckets or pots. Although the chain of pots was used extensively in Egypt and Spain, and by the Romans and Greeks, the most remarkable

installation is that at Joseph's Well at Cairo. Ewbank says that it is the most remarkable well ever made by man. "Its magnitude and the skill displayed in its construction, which is perfectly unique, have never been surpassed." This was written one hundred years ago and would probably be an overstatement today, but it is a truly remarkable work especially in view of its construction centuries ago, possibly when the pyramids were built. This well, which is shown in Figure 15 taken from Ewbank, is nearly 300 ft. deep in rock, in two sections, the upper about 165 ft. deep, the lower about 130 ft. At the top of the lower shaft is a chamber in which is the gearing for driving the lower chain of pots and a basin to receive the discharge. Into this basin the upper chain of pots dips. Both sets of chains are driven by mules and there is a spiral ramp around the upper shaft down which the animals are driven to the chamber at the junction of the shafts. Access to the bottom of the well is by a narrow spiral ramp cut in the faces of the walls.

A small Egyptian chain of pots is shown in Figure 16. This machine was classified by the photographer as a noria, but it is really a chain of pots, though it would seem to be on the border line.

Although the construction of the Aswan dam and the barrages on the Nile have introduced modern irrigation into Egypt in the last 30 or 40 years, primitive methods of lifting water still persist in that country; chains of pots which differ in no way from the machines in use on the same spots thousands of years ago are still common.

Vitruvius, who included the chain of pots among the devices described by him, represents the machine of the Romans as constructed with a double chain of iron and brass buckets. It was apparently our modern bucket elevator or conveyor in use close to 2 000 years ago.

It is probable that it was a chain of pots which raised the water of the Euphrates to the top of the walls of Babylon, 350 ft. high, where it was used to water the famous hanging gardens. No description of this machine has been preserved but, since it is always mentioned as a single engine and not a number of engines working in series, it could hardly have been any other device.

The following quotation from Ewbank who seems to have been somewhat of a philosopher, closes our discussion of this ancient and useful device: "The chain of pots was used by all the celebrated nations of antiquity and it still (1840) is employed more or less over all Asia and Europe. Previous to the 16th century, it constituted the 'water works' for supplying European cities, and was often driven by windmills — as it still is in Holland. It seems to be the *ne plus ultra* of hydraulic engines among half civilized nations, while those only which are enlightened, have the pump. Even the materials of which it is made by different people of old, may be considered as emblematical of their national characters. The inhabitants of Egypt, central and southern Asia, employed light and fragile materials; the ropes were fibres of the palm tree, and the vessels of earthenware; while the

Romans made the chains of iron and the vessels of brass. The former people were soft, effeminate and easily subdued; the latter stern, inflexible — an iron race."

The Chain Pump. Not so many years ago the chain pump was to be found in many farm yards in New England and no doubt there are still some left. This pump was always supposed by the writer to be the result of Yankee ingenuity, but he finds that in reality in one form or another it has been used for centuries and was probably first devised by the Chinese. Presumably it descended from the chain of pots. Numerous local circum-

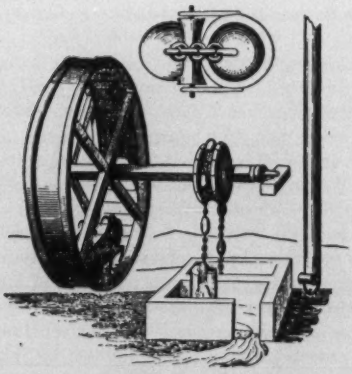

FIG. 17.— CHAIN PUMP.
(from Agricola.)

stances would frequently prevent the chain of pots from being used in a vertical position, and when its direction deviated greatly from the perpendicular, some mode of protecting the loaded vessels while ascending rugged banks became necessary. What simpler and more obvious device could there be than an open trough or wooden gutter through which they might glide? But such a contrivance could not have been used long before it became apparent that pieces of plank or any solid substance occupying the entire width of the gutter might be substituted for the pots since they would answer the same purpose by pushing the water before them when drawn up by the chain. From this point it would be but another step to cover the top of the gutter converting it into a tube which could be used in a perpendicular or any other position. This theory seems to be borne out by the fact that the Chinese are said to use this device in the open-gutter form.

This machine does not appear to have been known to the ancient Egyptians, Hindus, Greeks or Romans and is believed to have been intro-

duced into Europe from China though when and by whom is uncertain. It may have been independently conceived.

Agricola in his "De Re Metallica," first published at Basle in 1556, describes chain pumps in use for unwatering mines. Figure 17 is from that work. Another author of the 16th century describes a chain pump, operated by some form of windmill, in which there were two cylinders one on each run of the chain so that no matter in which direction the chain moved, one or the other of the cylinders was operative and whichever way the wind blew, the pump pumped.

Figure 18 shows an old pump used in the ship yards and docks at Marseilles operated by galley slaves who were relieved every hour. Note the use of leather cups on the hemispherical pistons, the chains on the slaves, and the hour glass.

These old machines, however, were so difficult to operate because of the enormous friction that they were not widely used, and we find them referred to in 1729 as "being out of date" in Europe. Subsequently, and not long after this, however, the chain pump was improved in design, materials and workmanship and found extensive use on board ships.

The Screw. We come now to another ancient machine for raising water which was one of those described by Vitruvius but which is in no way related to the primitive bucket. It is in fact original in every way and though appearing here in the class of bucket elevators is really in a class by itself.

The Archimedean or Egyptian screw illustrated in Figure 19 is believed to be the oldest hydraulic engine involving the use of tubes. Although Archimedes has been generally credited with its invention, it is not improbable that it is of even greater antiquity and that he introduced it to the Greeks after coming upon it in Egypt. Be that as it may, it is very old and interesting.

This machine has been constructed in a variety of ways; sometimes in the manner illustrated in Figure 19 using flexible tubes of lead or leather; sometimes in the manner shown in Figure 20 where the outer cylinder and the contained screw are fastened and rotated together; and sometimes where a screw constructed similarly to that shown in Figure 20 revolves in a fixed half or whole cylinder. Machines with half fixed cylinder driven by windmills were used by the Dutch. They have been employed in various parts of England for the drainage of marsh lands. There they were driven by horses. Screws with fixed cylinder, Figure 20, moved "by the walking of men" were used by the Romans.

Pumps.

The first known description of a pump is by Vitruvius (1st century B.C.), a translation of which by William Newton (1771) follows:

It remains now to describe the machine of Ctesibius which raises water very high. This is made of brass; at the bottom a pair of buckets (cylinders) are placed at a little distance, having pipes like the shape of a fork annexed,

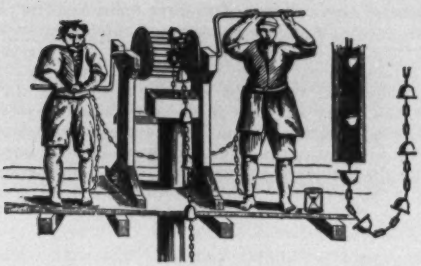

FIG. 18.— CHAIN PUMP OPERATED BY GALLEY SLAVES AT DOCKS AT MARSEILLES.

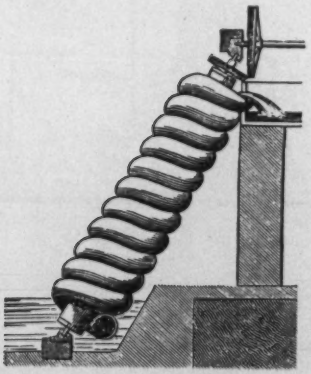

FIG. 19.— ARCHIMEDEAN SCREW.

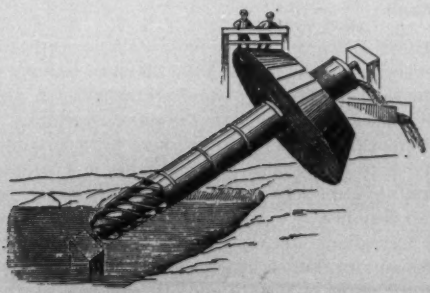

FIG. 20.— SCREW AS USED BY ROMANS.

meeting in a basin in the middle. At the upper holes of the pipes within the basin, are made valves, hinged with very exact joints; which, stopping the holes, prevent the efflux of water that will be pressed into the basin by the air. Upon the basin a cover like an inverted funnel is fitted, which is adjoined and fastened to the basin by a collar, riveted through, that the pressure of the water may not force it off: and on the top of it, a pipe called the tuba, is affixed perpendicularly. The buckets (cylinders) have valves placed below the lower mouths of the pipes, and fixed over holes that are in their bottoms: then pistons turned very smooth and annointed with oil, being inclosed in the buckets (cylinders) are worked with bars and levers

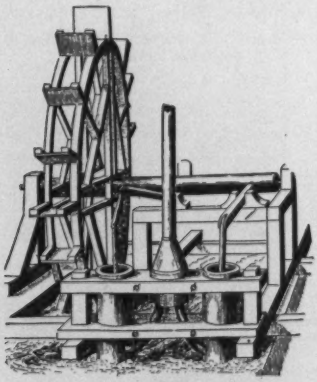

FIG. 21.— CTESIBIUS' PUMP — 200 B. C.

from above; the repeated motion of these, up and down, pressing the air that is therein contained with the water, the holes being shut by the valves, forces and extrudes the water through the mouths of the pipes into the basin; from whence rising to the cover, the air presses it upwards through the pipe; and thus from the low situation of the reservoir, raises it to supply the public fountains.

Figure 21 from Ewbank's book represents his conception of Ctesibius' pump. The levers raising the pistons are understood to have been operated by cams on the shaft of the water wheel which is shown probably on the strength of a statement by Vitruvius that whenever machines were employed to raise water from rivers they were worked by undershot wheels. This pump is really quite remarkable and embodies in a simple manner the essential elements of a modern single-acting duplex power pump including the use of an air chamber.

Ctesibius lived about 200 years before the Christian era. From that time to the 16th century there is little recorded concerning pumps. Vegetius a Roman military writer of the 4th and 5th centuries, however, has left a

description of a bellows pump, an illustration of which appeared in the first German translation of his published in 1511. This is reproduced in Figure 22.

In 1556 Agricola published a comprehensive work in 10 volumes entitled "De Re Metallica,"* which describes the operations of mining as practiced at that time and contains descriptions and illustrations of the machinery used for unwatering German mines. Among these are found chain pumps, piston pumps and buckets with windlass, which devices had no doubt been used in the same mines from the days when they were operated by the Romans.

It was in the 16th century apparently that pumps began to be applied to public water works, first in Germany at Augsburg and Bremen, later in

FIG. 22.— GERMAN BELLOWS PUMP — 1511.

England and in France. In most cases they were driven by water wheels. The early installations in England and France are well defined as to dates, but beyond the fact that those in Germany antedated them the writer has not been able to fix the time when they were built.

"One Peter Morris, a Dutchman, in the year 1582, contrived a water engine or mill to supply citizens (of London) with Thames water. This machine was first made to force the water to the height of Gracechurch Street only. He obtained from the city a lease for 500 years, at the yearly rent of 10s., for the use of the Thames water, and a place for sinking his mill upon."†

"This pumping machinery consisted of an undershot wheel which was 20 ft. in diameter, having 26 floats, 14 ft. long by 18 in. broad. Each wheel gave motion, by means of toothed wheels and levers, to 16 pumps, in such a manner that for every revolution the plungers made two and one-fifth strokes 2 ft. 6 in. long. The plungers were 7 in. in diameter, and when the tide flowed quickly the water wheels would together be thus pumping at the rate of 2½ million gallons in twenty-four hours."‡

*Translated into English by Ex-President and Mrs. Hoover. †Allen's History of London.
‡Frank H. Pond, quoted in Bjorling's Pumps, 1890.

Morris' pumping station proved so successful that he was granted the privilege of erecting another engine. Presumably the foregoing description is of both stations and the capacity that of both combined. The first was erected in the first arch of London Bridge; the second in the second arch. The pipes used were of lead.

When excavations were made for the north foundation of the present London Bridge about 1825, two cast-iron pump cylinders were brought to light together with a large square shaft much worn on the underside as though it had performed a reciprocating motion through an arc of about

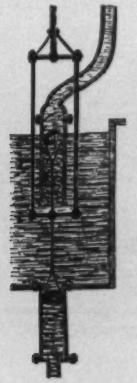

FIG. 23.— TYPE OF PUMP USED AT NOTRE DAME WATERWORKS, PARIS. Early 16th Century.

90 degrees. It is presumed that these were parts of some other early pumping station destroyed in the great fire which swept London in 1666.

During the reign of Henry IV of France (1589–1610) lifting pumps driven by water wheels were installed at Pont Neuf on the Seine to supply water to the Louvre and Tuilleries. This plant was successful and led to the erection of a similar plant at Pont Notre Dame. The type of pump used at the latter place is shown in Figure 23 (from Ewbank). It was composed of an atmospheric and a lifting pump in series. The plunger pump had not at that time been invented.

What is probably the most elaborate machine ever built for raising water was constructed in the 17th century at Marli, near Paris, for supplying the public gardens at Versailles from the Seine. It was put into operation in 1682. It deserves a brief description, not for the merits of its conception and design since it was singularly ill-conceived, but because of the great contrast which it presents to the practice of today and indeed to the prac-

tice developed within a few decades of its construction following the invention of the steam engine. The reservoir into which water from the Seine was raised by this machine was three-quarters of a mile from and 533 ft. above the river. This lift was divided into three steps. The first, discharging into a cistern 600 ft. from the river, had a lift of 160 ft.; the second had a lift of 185 ft. and discharged into a cistern about 2 000 ft. from the river; and the third had a lift of 188 ft. There were 64 pumps on the first lift, 79 on the second and 82 on the last, a total of 225, in addition to which there were about 25 more used to keep water at all times over the pistons of those

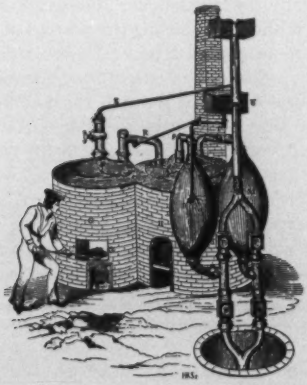

FIG. 24.— SAVERY'S "MACHINE FOR PUMPING WATER BY FIRE."

at the river. All these pumps were driven by 14 undershot wheels in the river through jointed rods, bell crank levers and walking beams. Think of driving pumps at a distance of three-eighths of a mile through such rigging and think of the leakage of 500 valves.

About the end of the 17th century, we find pumps used for public water supplies in Germany, France and England. That century saw also certain important discoveries and inventions having a bearing on the development of the art of pumping. In 1643, Torricelli explained atmospheric pressure; in 1674, Sir Samuel Moreland, Master of Mechanics to King Charles the Second, invented and patented the plunger pump; and the stuffing box was invented about the same time, probably by the same gentleman. But by far the most important developments were connected with the attempts made to apply steam to pumping, which culminated in the invention of the atmospheric engine by Newcomen.

Up to this time the greatest handicap to mining operations had been the expense of keeping the mines unwatered, and many rich deposits of

coal and ore were unworked because of the impossibility of pumping out the mines. There was thus a great incentive to invent practical means to do this work mechanically, and the minds of several mechanics and philosophers turned toward the use of steam, the expansive properties of which were more or less understood as was the fact that the condensation of steam in a closed vessel results in the creation of a vacuum. A few individuals appear to have built machines for raising water by steam; but just how is not known. Thomas Savery, however, invented and built a device which he patented in 1698. This machine, which is shown in Figure 24, worked. There were two closed receivers, M and I, each connected at the top with the boilers and at the bottom with the suction and discharge pipes in which were suitable valves A, B, E and F permitting the passage of water upwards only. Cold water, stored in an elevated tank, U, could be sprayed on either receiver. Steam being admitted to one of the chambers when it was full of water would drive the water out through the discharge pipe. The steam supply would then be shut off and the exterior of the vessel sprayed with cold water. This would condense the steam in the chamber and create a vacuum which would promptly fill the chamber with water from the source of supply. The chambers were used alternately — i.e. while one filled the other discharged. This machine was in fact the first pulsometer.

In 1699, Savery exhibited a model of his machine before the Royal Society of which Sir Isaac Newton was then president, and in 1702 published a complete account of it under the title "The Miner's Friend." He proposed that it be used not only for pumping of mines and for water-supply purposes but also for the generation of mechanical power by utilizing the water, pumped into an elevated tank, to drive a water wheel.

His "machine for pumping water by fire" never had extensive use, largely because of the limitations of his boiler. Although he devised a second boiler, G, which in effect was a feed-water heater in which he heated the make-up water before injecting it into the power boiler, and although he invented gage cocks to determine the height of water in his boilers, he had no safety valve, and the operation of this machine must have been attended with considerable danger. Furthermore, the height to which water could be lifted in this manner by one machine was limited by the steam pressure used which in turn was decidedly limited by considerations of safety. To raise water to considerable heights as in mining service, it would have been necessary to operate several machines in series. Savery himself in "The Miner's Friend" suggests spacing them 60 ft. apart vertically which would indicate, allowing for a suction lift of 10 to 20 ft., and a forcing lift of 40 to 50 ft., a steam pressure of about 22 lb. per. sq. in.

About the time that Savery was perfecting his device and trying to persuade the mine owners to use it, a blacksmith and a glazier of Dartmouth in Devonshire were at work on experiments which finally resulted in the invention of the first steam engine. To them, Thomas Newcomen and John Cawley, respectively, belongs this distinction though their

invention was what is called an atmospheric engine and not the steam engine which we know today. That resulted from Watt's improvement of their machine.

Newcomen's engine is best understood by reference to Figure 25, which shows it as first developed. Steam from the boiler is admitted to the cylinder below the piston. The cylinder is open at the top. When the pressure of the steam below the piston is equal to the atmospheric pressure on its top surface, it is raised by the counterweight on the pump rod suspended from the opposite end of the walking beam. The steam supply is

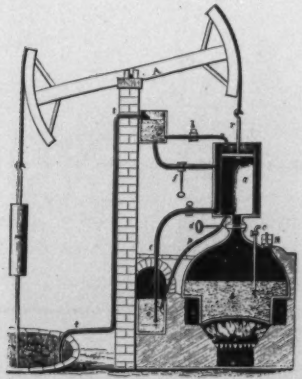

FIG. 25.— NEWCOMEN'S FIRST ENGINE.

then shut off and cold water is circulated through the water jacket on the cylinder. The steam in the cylinder is thereby condensed, producing a vacuum below the piston which is then driven downward by the pressure of the atmosphere on its upper surface. This movement lifts the pump rod and counterweight. The cooling water is then drawn off and the operation repeated.

This cycle required some time, consumed principally in the condensation of the steam. For this a remedy was found by pure accident. The attendants were one day surprised to see one of these engines make several strokes much faster than usual and upon searching for the cause found that a small hole through the piston was permitting a flow of water into the steam end of the cylinders from the water seal of 2 or 3 in. kept on top of the piston to prevent air leakage. This spray of cold water condensed the steam almost instantly and resulted in the increased speed noted. This led Newcomen to abandon the water jacket and substitute an injection of cold water directly into the steam space.

When Newcomen and Cawley applied for a patent they were opposed by Savery who claimed that the creation of a vacuum by the condensation of steam was an infringement of his invention. Since he was a man of means and considerable influence at court, Newcomen and Cawley followed the line of least resistance, admitted him to a share in the profits, and the patent, issued in 1705, was in the name of all three.

Newcomen's engines were found to answer the purpose of raising water so well that in a few years they were introduced into Russia, Sweden, France and Hungary. About 1760 one was imported to this country for use at a

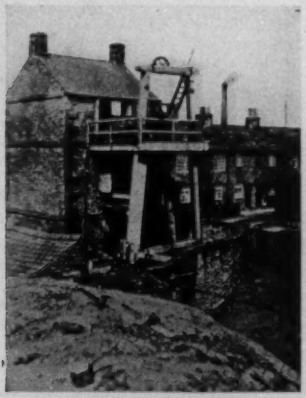

FIG. 26.— NEWCOMEN ENGINE AT ELSECAR, YORKSHIRE, ERECTED 1787.
Still standing and in operating condition.

copper mine near Belleville, New Jersey. These engines were most extensively used in mines, but were also employed for public water supplies and even to supply water wheels of mills. About the year 1767 one of these engines was erected at the London Bridge water works, previously mentioned in this paper, to raise water at neap tides and as a security against fire during the turning of the tide when the water wheels were necessarily idle.

There is today in Elsecar in Yorkshire a Newcomen atmospheric pumping engine, which is probably now the only engine of this type in the world. It is still in operating condition though not used (see Figure 26). It was run in 1931 for the benefit of the "Newcomen Society for the Study of the History of Engineering and Technology." The Elsecar engine was superseded by electrical pumps in 1923. Up to then it had been operated from the time of its erection, probably 1787. But in 1928 "a very heavy

rainfall brought about drowning of the electrical pumps," and the old engine was started and once again "nodded its head." The Elsecar engine has a 48-in. diameter cylinder and 5-ft. stroke, makes 6 strokes a minute and delivers 50 gal. per stroke against a head of 129 ft. The steam pressure used is about 2 lb. per sq. in. It is a huge affair and develops about 10 or 12 h.p. or a fraction of that developed under the hood of an automobile. But where would the automobile engine be after 140 years' use! An interesting and more detailed account of this engine and of another recently demolished in the same vicinity, by H. W. Dickinson, President of the Newcomen

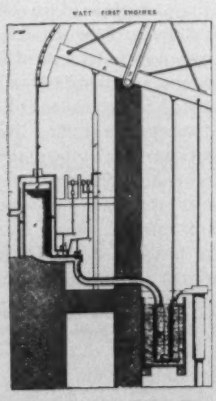

FIG. 27.— WATT'S FIRST ENGINE.

Society, may be found on p. 663 *et seq.* of the December, 1934, number of "Water and Water Engineering."

Newcomen's engine, in its original form, was exceedingly crude, but as time went on it was improved here and there by Newcomen himself and by others. As has been said, condensation by jacketing the cylinder with cold water was soon abandoned in favor of the injection of cold water into the cylinder. Nor was it long before mechanical means were devised for operating the valves. Originally an operator was charged with opening and shutting the steam valve and the water injection valve by hand. These movements had to be made with considerable precision. Failure to time the closing of the injection valve and the opening of the steam valve might prove disastrous. Certainly the apparatus would be subjected to severe shock if the fall of the piston was not properly cushioned. The first attempt at mechanical valve operation was made by a youth who hooked up the valves with the walking beam by means of strings. Soon afterward more substantial gear was invented.

But with all such and other improvements, the engines were exceedingly expensive to operate and even at coal mines the value of the fuel consumed was appalling to the owners. Attempts to improve the efficiency of the boilers were numerous but still the cost of pumping was very high. It was not until about 1765 that the true cause of the inefficiency of the machine was discovered by James Watt, a young instrument maker of Glasgow, to whom a model of a Newcomen engine was sent for repairs.

Previous to this time Watt had been interested in steam and had made some experiments in which he had moved the piston of a syringe by steam pressure. Consequently he was greatly interested in the model submitted to him, and in studying it he soon realized its defects and determined that the losses of heat in the cylinder and the imperfect methods of condensing the steam were the primary causes of its lack of efficiency.

He accordingly set about contriving an independent condenser into which the steam was exhausted to be condensed. Furthermore, by closing the top of the cylinder and applying a stuffing box to the piston rod he was able to substitute steam pressure for atmospheric pressure on the piston. Figure 27 shows Watt's first engine diagrammatically. With the piston at the top of its stroke, as shown, the valve h is closed and valve k on the connection to the condenser m is opened. Steam comes through connection g. The piston therefore in the position shown has steam pressure on its top side and a vacuum beneath, both impelling it downward. At the end of its down stroke, k is closed, shutting off the condenser, h is opened admitting steam beneath the piston and equalizing the pressure on both sides of it, whereupon it is raised by the weight of the pump rod and counterweight on the opposite end of the walking beam.

Watt, in 1769, had obtained a patent "for a saving of fuel in Fire Engines" which covered the essential features of this engine but it was not until 1774 that a sizable model was constructed and demonstrated to a gathering of mine operators. Realizing then that additional years would be required to perfect his machine to the point which he desired, being fully aware of its weak points and having many ideas for improvements which he wished to try out without endangering his opportunities for profit, Watt petitioned parliament at this time for an extension of his patent. This was granted, and his patent was extended to 1800 which, incidentally, did permit him and Mathew Bolton, his financial backer and the builder of his engines, to amass a considerable fortune as a result of their labors.

Watt soon devised important improvements including provisions for making the engine double-acting, the addition of reliable valve gear and the perfection of the condenser and air pump, a problem which gave him considerable trouble. With the use of the steam expansively, the application of a throttle valve, fly-ball governor, crank and fly-wheel, the steam engine we know had practically arrived.

These improvements were largely brought about by the demand for a steam engine to drive revolving machinery at constant and controlled speed.

The original atmospheric engine and the steam engine of Watt were the result of the demand for mechanical power to operate pumps in mining service for which the single-acting engine was admirably adapted. The standard arrangement of mine pumps until the development of the direct-acting steam pump was a series of pumps in a shaft all operated by a single rod suspended from the end of the walking beam of the engine. The bottom pump was a lifting pump with suction pipe dropping into a sump at the bottom of the shaft. The other pumps were plunger pumps driving the water upwards on the down stroke. Each pump discharged into a cistern from which the pump next above drew its supply. Thus the actual pumping was done principally on the down stroke of the pump rods and since these were heavier than the load of water lifted, the only work required of the engine was that of lifting the rods, which was the down stroke of the engine piston. This arrangement and the single-acting engine came to be known as the Cornish system and Cornish engine.

Pumping Water in the United States.

The first public water supply in the United States to employ pumps was that of Bethlehem, Pa., the construction of which was begun in 1754 and finished in 1761 by Hans Cristopher Cristiansen, a Danish millwright. His pump was constructed of lignum vitae and driven by an overshot waterwheel.

The first steam pump in America was the Newcomen engine imported in 1760 to drain certain New Jersey mines as already noted in this paper. The first Newcomen pump for public supply was erected in New York shortly before the Revolutionary War.

The first steam pumping engines to be built in the United States were put in operation at Philadelphia in 1801. A low-lift pump raised the water from the Schuylkill River at the foot of Chestnut Street to an open basin from which it flowed by gravity through a conduit in Chestnut Street to Center Square, now the site of the City Hall. There it was lifted by pumps into wooden tanks on the top of a building. Both pumps were double-acting force pumps, and the engines had wooden walking beams and flywheels. "The boilers at both plants were wooden boxes, 9 ft. high, 9 ft. wide, and 15 ft. long, of 5-in. white pine plank thoroughly bolted and braced. The firebox, constructed of wrought-iron plates with vertical cast-iron flues, was inside. The engines were of the Watt vertical, double-acting type attached to a Cornish (?) pump. The pump of each engine was of wood lined with copper."*

Shortly after 1811 two steam engines and pumps were erected at Fairmount (Philadelphia), and a reservoir was constructed, but the expense of steam power proved so great that the engines were abandoned, a dam built and waterwheels erected to drive the pumps.

*"Historic Review of Water Works Development in the United States," by the late George W. Fuller Trans. Am. Soc. Civ. Eng., 1928.

Before the completion of the Croton supply in 1842, New York had a public supply drawn from wells, first, in 1797, by common forcing pumps worked by horses; later, in 1804, by double-acting pumps driven by one of Watt's engines which continued in operation until Croton water became available.

During the last century there was a static period in the field of pumping due, chiefly, to patent conditions, until the sixties. The smaller pumps were usually direct-acting and the larger were of the Cornish type. The direct-acting pump was not invented until 1840. At that time Henry R. Worthington, while experimenting on the application of steam to canal navigation, built the first of these for a boiler-feed pump. The manufacture of such pumps was begun in South Brooklyn in 1850 and in 1855 the first direct-acting Worthington pump for water-works service was put into use at Savannah, Ga. In 1863 the first duplex Worthington pump was erected in Charlestown, Mass. It had a capacity of 5 m.g.d.

About 1860, there began a lively competition among builders of pumping machinery for the rapidly expanding market for pumping engines in the public water-supply field, which, during the succeeding quarter century, resulted in the development of the best known steam pumping engines and a tremendous improvement in steam economy. During this period we find the Cornish engine soon giving way to more modern types, though not at once, apparently, since one was designed and built at Providence in the early seventies. This has been admirably described and illustrated in a paper by James A. McKenna.* A vertical compound engine built by I. P. Morris was put in service at Lowell in 1873. This engine employed both a walking beam and flywheel. In the same year E. D. Leavitt's first high-duty flywheel engine was put in operation at Lynn and at about the same time, during a period which seems to have been one of particular uncertainty as to design, Corliss built for the city of Providence the peculiar pumping engine dubbed "The Spider" which is described by Mr. McKenna in the paper referred to previously. In 1882, the first Holly-Gaskill engine was erected at Saratoga Springs, N. Y.

It was at the close of this period that the Allis or Reynolds triple expansion pump was designed, the first being built for the city of Milwaukee in 1886. This type soon became the standard high-duty, large-capacity, American pumping engine.

By 1900 certain types of pumping engines for different kinds of service were rather definitely established. Those interested will find them described by Irving H. Reynolds.†

The Twentieth Century and the Present Trend

The outstanding development in pumping during the 20th century has been the widespread adoption of the centrifugal pump which, in the

*Journal New England Water Works Association, Vol. 40 (1926), p. 466.
†Transaction, Am. Soc. Civ. Eng., Vol. LIV (1905), Part D, p. 513.

past 20 years, has been carried on to the practical exclusion of any other kind of pump in the water works field. In the opinion of those best qualified, to know there will probably never be another large triple expansion pumping engine built.

The first centrifugal pump resembling that of today, it is believed, was designed and built in the United States in 1818. Its casing was very similar to that of the modern pump, but the impeller was only a paddle wheel with radial vanes. It was in 1846 that William D. Andrews brought out a centrifugal pump with an impeller of the enclosed type with vanes curving backward.

The early centrifugal pumps were suitable only for low head and low speed and were, therefore, not adaptable to water-works service. At about the turn of the century, however, the commercial development of the steam turbine and of the high-speed electric motor made possible the application of centrifugal pumps to higher heads, and rapid progress was soon made in the introduction of pumps of this class into a great variety of fields. Water-works engineers, however, were slow to be convinced that the small high-speed centrifugal pump possessed the efficiency, reliability and durability needed for public service.

Before 1914, pumping engines were supreme in this field, and the vertical triple expansion engine was the *ne plus ultra*. Between 1914 and about 1926 there was a marked trend to steam turbine reduction-gear-driven centrifugal pumps. Since 1926 there has been a decided trend toward electrically driven units in the large sizes, and this trend appeared even earlier in connection with smaller units.

The remarkable growth in the use of centrifugal pumps in water works is evidenced by the following table* which shows the total capacity of centrifugal pumps supplied to municipal plants at successive periods by one manufacturer:

Year.	Total Capacity, m.g.d.
1907	52
1910	150
1915	1 350
1920	3 500
1930	14 000

Coincident with the growth in the use of the centrifugal pump during the past 20 years has been an increase in efficiency averaging probably 15 per cent., half of which has been accomplished in the last 10 years. This improvement has been due mainly to the higher speeds available in the driving element and better hydraulic design resulting from extensive shop testing and experimental research. Improved mechanical features have played a negligible part.

The principal reason for the abandonment of reciprocating pumps in favor of centrifugals lies in first cost. Roughly, a vertical triple expansion

*A. Peterson, *Journal Am. Wat. Works Assn.*, October, 1933.

pumping engine installation costs three times as much as a steam turbine reduction-gear-driven centrigugal pump of equal capacity and fifteen times as much as an electric motor driven centrifugal, costs in all cases being for a complete pumping station including foundations, buildings, boiler plant and accessories. This high first cost is not offset by the greater economy of the more expensive units.

Although record duties as high as 215 million foot-pounds per thousand pounds of steam have been attained with triple expansion engines, steam turbine gear-driven centrifugal pumps have been so perfected in both turbine and pump ends that they are capable of coming within 8 or 10 per cent. of such duty when operating under the same steam conditions. An official test of a 60-m.g.d. steam turbine driven pump unit working against 300-ft. head, installed at Milwaukee in 1932, gave a duty in excess of 195 million foot-pounds per thousand pounds of steam as compared to 214 million foot-pounds per thousand pounds of steam for the pumping engines in the same station. The steam turbine, however, can utilize to advantage much higher steam pressures and temperatures than those used by engines; had the turbine at Milwaukee had the advantage of such steam conditions, it is probable that the duty of the turbine pumping unit would have practically equalled that of the engine unit. Furthermore, this 60-m.g.d. unit occupied only the space required for a 20-m.g.d. engine.

It was but natural that the earlier installations of centrifugal pumps for water works should have been made with steam turbine driving units. In many, if not most instances, such units were installed in existing stations either as replacements of obsolete inefficient machines or as enlargements of capacity in existing stations, or both, where the boiler plant was already built with sufficient, or at least provision for additional, capacity. Then too, electric service if available, was often of questionable dependability. In most cases this would place it out of consideration. With improvement of electric current supply, lower effective rates, multiple sources of supply and in many sections increased political pressure on the part of public service companies, the tide has swung strongly to electric motor-driven units.

The centrifugal pump has now been developed to the point where efficiencies of about 90 per cent. or a little more may be obtained.* This, in the opinion of designers, is about the maximum which can be hoped for. The steam turbine has been improved to the point where its economy when combined with the modern centrifugals is about the same as that of the triple expansion pumping engine. The electric motors applied to centrifugal pumping units, especially the synchronous motors, which type is almost universally used for pumping in sizes over 100 h.p., now have extremely high efficiencies, (96 to 98 per cent.).

In the Brilliant Pumping Station of the city of Pittsburgh, put in operation in 1932, 28-m.g.d. synchronous motor-driven units at 365-ft.

*In large units

head, have yielded an average overall efficiency, that is from wire to water, of 87.5 per cent.

At Chicago, two 75-m.g.d., 2 300-h.p. steam turbine driven units at 150-ft. head, using 300 lb. per sq. in. steam pressure and 200° F. superheat, have attained a duty of 218 million foot-pounds per 1 000 lb. of steam.

There are now also in the field of driving machines, the gasoline and the Diesel engine. The former has found application principally in standby units. In some instances dual drive has been employed, with a motor at one end of the pump shaft and a gasoline engine at the other, the usual operation being by the motor with the engine in reserve for emergency use.

The Diesel engine is increasingly used for water-works service in sizes below 400 h.p. This is because of a growing recognition of the economy and reliability of this machine and the influence, in some localities, of the high cost of electric energy, of the lack of or unreliability of purchased power supply and of the low cost of fuel oil. The application of the Diesel engine to water works has been admirably covered in a paper by Rodney D. Hall of the Worthington Pump and Machinery Corporation.* In that article he makes the following significant statement: "The present development of the Diesel engine applied to water-works service, and the future expansion in its use which seems assured, cannot help but command attention."

Summary and Conclusion.

The present situation in the water works pumping field and the trend may be summarized as follows:

The day of the reciprocating steam pump for new installation is over.

The centrifugal pump with electric motor, Diesel engine or steam turbine drive is now generally adopted for almost all services.

Efficiencies of about 90 per cent. are now obtainable in the larger centrifugal pumps, and designers do not expect materially to raise this figure.

The electric motor is most generally employed as the driving element with centrifugal pumps, synchronous motors being generally used in sizes over 100 h.p.

The steam turbine is specified as prime mover for centrifugal-pump installation in existing steam pumping stations and is finding some application for driving simultaneously centrifugal pumps and electric generators. The steam economy of the modern steam turbine driven pump is high.

The Diesel engine is being used increasingly in sizes under 400 h.p. in situations where it can compete with other prime movers.

The Diesel engine appears to be still in the development stage, and rapid strides are being made in reducing the weight and consequently first cost per horsepower.

*Journal Am. Water Works Assn., Vol. 23 (1931), p. 337

In this historical review the writer has touched only the high spots. It has been a problem to determine what should be included and what omitted, and the omissions are many. But to make such a paper comprehensive would require so much space that a substantial volume would result. Such a work when completed would be tedious to read and all in all of doubtful value. The writer very soon made up his mind to tell only a story rather than to prepare a book of reference. In doing so he has included those historical facts which he believes to be of greatest importance and which most interest him personally, leaving out the great mass of data concerning devices, machines and men which have been essential to but of relatively minor importance in the development of the art of pumping.

TASTE AND ODOR CONTROL IN PUBLIC WATER SUPPLIES.

BY JAMES M. CAIRD.*

[*Read September 19, 1934.*]

Of late years we have heard a good deal regarding the subject of odor and taste and the methods of determining odors and tastes. But the question is not new. If you will study the Good Book you will find that Moses had trouble when he led his people out of Egypt; the new country was very good but the water was not; it was bitter, and Moses put some salt in it and the water became sweet. But there is no record of what that salt was.

To taste is to have a particular flavor. An odor is any smell, whether fragrant or offensive; and with the latest devices for determining odors, there is a lot to be gained from determining the odor and trying to classify it when examining a water.

Regarding taste,— it is all right to taste some waters if you know their source, but there are some which I would not care to taste and would not want any of my assistants to taste. It is a pretty ticklish thing to taste some waters, especially raw waters, but of course some of us are inoculated and can take some chances.

Even trained observers will classify odors and tastes differently. It is pretty hard sometimes to get different observers to classify the same odors and the same intensities, as many people are more sensitive to odors and tastes than others. I have classified some thirty odors and tastes, but my descriptions are far from perfect. I would not dare to give you the descriptions of odors and tastes as classified by some of the water consumers.

Some of the causes of these odors and tastes are the decomposition of vegetation, such as grass, leaves, weeds, and algae. Then there are the trade wastes. I think that trade wastes are the hardest wastes to handle. The vegetable tastes we can generally take care of easily, but the trade wastes are pretty complex things. There are gas-house, sewage, canning, oil well, pulp mill, road material, pipe coating and dead-end odors and tastes.

There is another class of taste trouble in places that have two water supplies, only one of them being used at a time. There may be no objectionable odor or taste to either supply, but one supply has a hardness of about 100 p.p.m., while the other supply has a hardness of about 35 p.p.m. Every time we switch from one to the other we always hear from the consumers. It doesn't matter which way we switch. Personally I think hard water is generally very pleasant to the taste,— at least, I like a hard water.

We come next to the vegetable odors and tastes, which of course are associated principally with the algae. The word algae covers a multitude

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of sins. The growth comes and goes, and we can take care of it fairly well if we are just one step in advance. The only way you can keep ahead of it is to keep watching pretty closely and to have a good eye and a good microscope. When you begin to see things moving, it is time to get moving yourself.

It is surprising how small an amount of oil produced by algae will impart a disagreeable flavor. Comparing this with other oils, such as that of peppermint, we find that one part to fifty million parts of water will impart a flavor which can be detected. When we consider chemical wastes, such as phenols, we find that with the addition of chlorine, one part of phenol in 750 million parts of water will cause complaints.

There are cases where the water as it is drawn from the tap has a much more distinct odor and taste than when it is examined directly at the source. That is due generally to algae that have been broken up and have liberated their essential oils in passing through the mains.

What are we going to do about all this? Years ago it was considered proper to strip a reservoir before it was filled. That was going to be the cure-all. It did not work. A lot of money was spent on stripping in some places. Of course it is a very good thing to remove organic matter from the reservoir area, but this has not prevented algae growths with their resultant odors and tastes.

I find that a pretty good way of handling reservoirs is not to let any water go over the spillway if you can help it. Open the blow-off valves at the bottom of the reservoir and draw off the material that has accumulated on the bottom. This will help a lot. If you get rid of some of these deposits, you will not have so many serious troubles during the "turn-overs."

Another taste which is rather disagreeable at times is described as a metallic taste. This is due generally to what may be called "active" water standing for some time in service pipes. At times a distinct metallic taste results. Generally a flushing will remedy that trouble.

In the case of filtered waters, it was thought that with filter plants and filtered water all of our troubles would be at an end. But we soon found that filtered water, when stored in reservoirs and exposed to air and light, supported algae growths. The best thing to do is to cover such reservoirs. Either have the filtered water kept in a covered reservoir or be certain that the water only has a short storage time in the open reservoir. Then a little treatment will probably take care of it.

As to phenol wastes, which have given a great deal of trouble in some sections of the country, it has been found in some places that discharge of wastes from gas houses into the city sewers and mixing them with sewage is a great help. This practice seems to destroy the phenols, and it has also been found that phenols do not interfere with bacterial action at the sewage disposal plants.

In this section of the country, and also in the West, we have a good deal of trouble with sulphite wastes. In some places we treat such waters

by superchlorination followed by dechlorination. Also we have found chlorine and ammonia effective.

I have never been able to find that any of these odor and taste troubles which I have mentioned have had any detrimental effect on the health of the consumer. But there is the danger that if the water does not taste pleasant the consumer may take water from some unknown source, a well or a spring, which may be polluted.

Some people advocate the use of aërators. These do remove a good many odors. Some of the aërators, I feel, would be better if they were more efficient atomizers. In other words, the spray should be broken into finer droplets than is accomplished by some of the aërators on the market. Then there is ammonia. Ammonia works in some places but not in others. The use of activated carbon has been a great step in advance, certainly, in a good many places.

But we still go back to copper sulphate in our algae treatments. A method which has been used in the South is the pouring of creosote on a reservoir to kill the algae. I never dared to try that.

Then there are the filtration plants. It has been my experience that the slow sand-filter is a little more efficient than the rapid sand-filter in removing odors and tastes.

We have also used lime in places for some flavors and it has been effective. I have had very little experience with ozone and do not care to say much about it yet. Permanganate of potassium has also been used with success in some places to handle waters containing phenols. Sodium hyposulphite, and sulphur dioxide have been used for removing an excess of chlorine. With ultra violet rays I have had no experience. I have had some experience with absorbing clay; which sometimes has been successful, and at other times not.

There are some water conditions about which we still know little. The only way we can find out what to do is to keep busy. Each case is an individual matter. We have to work out the treatment which is best adapted for that particular condition.

TASTE AND ODOR CONTROL IN THE SMALL PLANT.

BY R. G. YAXLEY.*

[*Read September 19, 1934*]

Operating troubles and remedies are not necessarily confined to the larger plants that treat difficult waters. Tastes and odors, I think I am safe in saying, present to each plant a separate problem. No patent cure-all or sure-fire method should be considered simply because it worked somewhere. Our experience at Waterford, N. Y., has the additional limitation of being confined to a mechanical filter plant using river water averaging about 30 p.p.m. in alkalinity, about the same in hardness, and with a color from 30 to 70 p.p.m. The water is well loaded with the products of vegetable growths in swamps and shallow ponds and is polished off with sulphite wastes from paper mills. The result is most persistent grassy or woody tastes and odors that are especially pronounced when the water is heated. Shower baths make fine demonstrators.

I might enumerate some of the things we have tried: Pre-chlorination, with and without ammonia; permanganate of potash added to the raw water, to the basins and basin effluents; sodium aluminate before and after alum application with much difference; activated carbon every place from the raw water pump suction to the top of the filters; and last, but not least, sulphuric acid for pH correction.

Experience has taught us that the most important single item is to obtain the highest possible quality of basin effluent. Therefore, our basins have been fitted with baffles to prevent short circuiting, air jets have been employed for conditioning of floc, and sulphuric acid has been used with the alum to obtain pH control. These changes, with a spray-nozzle type of aërator handling filter effluents, made such an improvement that we said "perfect," that is almost, but some of our consumers did not agree. The next major step was the trial of activated carbon. Doses of from ½ to 9/10 of a grain per gallon of raw water did not entirely clear away the trouble, but it did cut filter runs about 50 per cent. and raise hob with chemical costs. More recently pre-chlorination with ammonia was tried with reasonable good success during the winter months, but with the advent of warm weather and high water-temperatures, nitrites appeared and bacterial growths developed in the filter sand. With 20° C. counts in basin effluents rarely above 10 and an apparent chlorine excess at all times on top of the filters, the clear well counts were in the hundreds. The best information available indicated that the ammonia was to blame, so it was discontinued and plain pre-chlorination used. The application of the

*Superintendent of Water Commissioners, Waterford, N. Y.

chlorine-ammonia treatment to the plant effluent was out of the question as consumers are so near to the plant the time element was too short. Trial also proved it to be of no value.

Our present procedure is heavy pre-chlorination, at times this summer it has reached 3 p.p.m. without showing any excess in the filter effluent; alum, with sulphuric acid when necessary; proper mixing and conditioning to obtain maximum basin efficiency; and sufficient secondary chlorine to give between 1/10 and 2/10 p.p.m. excess. This gives practically a tasteless product, but a slight odor is still present, at times, especially when the water is heated. As an emergency stand-by for extreme conditions we maintain a dry-feeder loaded with carbon. Our pumping rate is 50 000 gal. per hour, and we find that the application of about 2 lb. of carbon to the basin effluent during a 10-minute period, the dose being applied every 2 or 3 hours, will clean up objectionable conditions in fair shape without decreasing filter runs to any marked extent.

You will note that in connection with the use of chlorine and ammonia we had an apparent chlorine excess on top of the filters. Reports, recently made public from several sources, show that under certain conditions orthotolidine is not a reliable indicator for excess chlorine when ammonia is used. Where nitrites are formed these may cause orthotolidine reactions and false readings in a somewhat similiar manner to manganese. Test runs at our plant during August, 1934, on three successive days showed the chlorine excess on filters to be 0.15, 2.00 and 0.20 p.p.m. respectively. The pre-chlorination feed was about 2¼ p.p.m. each day. On the second day 0.4 p.p.m. of ammonia was applied, other conditions remaining the same. The logical conclusion is that either the ammonia formed some compound or by-product that reacted with orthotolidine, or the ammonia so retarded the chlorine that it did not have time to be absorbed by the organic matter in the water during the 2½-hour travel through the basins. Either of these reasons was sufficient to warrant discarding the ammonia. A comparatively short time ago ammonia was the latest thing in cure-alls, but now there seems to be ample authority for the statement that ammonia is of little value as a taste preventive if the taste is present before the chlorine is applied. The ability to carry a reasonable excess through a distribution reservoir or into the grid system is another subject.

We are particularly fortunate in having a plant well adapted to experimental work,—a somewhat rare condition. The original design provided two sedimentation basins to operate in parallel and four filters. It required but a few minor changes to fit the plant so that in effect it could be operated as two distinct units from the time the raw water entered until it passed into the clear well. This is of the utmost value, as one side can be run as a control while experiments are being tried with the other. Tests that require several days are not very reliable when using a river water supply if the entire plant has to be used. Changes may occur from one day to another that make comparisons useless.

Broadly speaking, I think the solution of many plant troubles can be found in proper operation. The day has passed when slipshod, rule-of-thumb methods will answer. The public is being educated to demand a far different product from that satisfactory a few years ago, and the operator or manager who fails to realize this is just looking for trouble. The equipment required to place a plant under laboratory control costs but a small amount, and no great intellectual efforts are required to use it. The reduction in operating costs alone may be surprising. In our case, the latest attack on the taste problem, through the use of pre-chlorination, has reduced our chemical costs over 5 per cent. during the summer months by the unforseen raising of the optimum pH point in the coagulation process. Filter runs have increased, and the time required for each wash has decreased. There is also the intangible benefit derived from a better product.

Did you ever wonder what constitutes one of the main incentives behind the word "research" that is so frequently mentioned these days? I think it could well be stated as "dissatisfaction with what is." Let us not neglect the lesson these words can bring into our chosen field.

Discussion.

Linn H. Enslow.* I do not believe I have much to add of particular value. I am rather interested in Mr. Yaxley's experience with the ammonia-chlorine treatment of a raw-water versus straight pre-chlorination. I am in agreement with him on his method of working out the problem. When I say I am in agreement, I mean that other recent experiences check with his. The use of a rather heavy dose of chlorine is preferable to a lesser amount of chlorine in contact with these organic bodies which produce tastes. On account of the greater oxidizing action of the straight chlorine over and above that of the chloramines the ammonia is best held out for application to the filtered water. Whether or not he had nitrites in his effluents in winter is a matter of some question. I would say it was more likely residual chlorine because the nitrite-producing bacteria, if there in winter, are not active at low temperatures.

Mr. Yaxley. There is much difference between summer and winter.

Mr. Enslow. I thought you said the filter effluent was rather sterile in winter and not in summer. It is true that the ammonia-chlorine treatment of raw water does cause the filters to unload their burden of filth that they have taken out on the surfaces of the sand grains. That is to be expected and has frequently given rise to an inferior effluent and tastes resulting.

Mr. Yaxley. I wish to again emphasize the fact that these counts in our filter effluent and clear wells developed after the warm weather commenced. We had been using pre-chlorination and ammonia throughout the cold weather. Our count in the clear wells and filter effluent was, I

*Editor, Water Works and Sewerage, New York, N. Y.

think, many times at the zero point. After the weather got warm the counts commenced to increase in the filter effluent and clear wells, while the basin counts remained the same as they had in the cold weather. We can, therefore, leave out any question of filter sand unloading, because those filters had been dosed with chlorine and chloramines for weeks, until they were producing an absolutely sterile effluent. Then these counts commenced to show up.

MR. ENSLOW. When the water was warm, did you have a positive test for chlorine in the filter effluent?

MR. YAXLEY. No; it petered out on us. Tests made on top of the filter showed 0.7 or 0.8 p.p.m. but the chloramine in the filter effluent had disappeared.

MR. ENSLOW. You see your filters were unloading all the time, and you had excess chlorine going through in the cold weather, and consequently that was sufficient to produce samples with low bacterial content from the filters. In the warm weather, though, the residual chlorine had disappeared as is commonly the case. Even so, you might be surprised to know that the end products of chloramine have quite an effect in unloading filters. Then, you have no residual chlorine left to kill the bacteria which are being released by the sloughing off of deposited material on the sand and gravel.

MR. YAXLEY. I had intimated that the unloading process had been completed before this warm weather began.

MR. ENSLOW. You carry now a residual of between 0.1 and 0.2 p.p.m. in the filtered water as the result of secondary chlorine application?

MR. YAXLEY. Yes.

MR. ENSLOW. With such heavy pre-chlorination does that not give you the taste of chlorine in the finished water?

MR. YAXLEY. No.

MR. ENSLOW. I am bringing this point out because there may be someone in this room who might not understand that as a result of heavy pre-chlorination, the chlorine demand of the filtered water is much less and usually residual chlorine values in the finished water cannot be carried so high without taste or odor of chlorine being noticed at the consumer's tap.

CONTROL OF TASTES AND ODORS IN THE WATER SUPPLY OF ROCKPORT, MASS.

BY G. C. HOUSER.*

[*Read September 19, 1934.*]

Ever since the year 1922, the public water supply of the town of Rockport, Mass., has been subjected to treatment with copper sulphate, for the control of microscopic organisms which give rise to the occurrence of objectionable tastes and odors.

Rockport, located on Cape Ann, is one of the popular summer resorts of the Massachusetts coast. The number of people living in the town during the summer months is about three times the official population. The permanent population of the town, according to the 1930 census, is 3 630, while the summer population of 1934 is estimated to have been about 12 000.

Sources of Water Supply. The principal source of water supply for the town is Cape Pond, a natural body of water, located in the southerly part of the town. The watershed consists largely of woodland, covering an area of approximately 0.4 sq. mile. At ordinary high water the pond itself has an area of 43 acres, with an average depth in the neighborhood of 12 ft., a maximum depth of 23 ft., and a total storage capacity of 183 m.g. Water is drawn out of the pond at a depth of 15 ft. below high-water mark and is chlorinated before being pumped to two standpipes for distribution to the mains.

Cape Pond has no inlet of any consequence, but a small intermittent outlet finds its way through a swampy area at the western shore. At the northerly end of the pond there is an area of low swampy land of 10 acres or less. During the winter of 1930–31, a system of ditches was dug in this area, in order to drain water from it into the pond when the latter is not filled. In view of the absence of any inlet of material size, it appears probable that the pond is largely spring-fed from ground waters collected in and percolating through the glacial drift deposits, of which the watershed is largely composed.†

For many years the entire water supply was obtained from Cape Pond, which was so seriously taxed at times that the water commissioners found it desirable to restrict the use of water, particularly for sprinkling. In 1926 an auxiliary water supply was developed from four tubular wells in the valley of Mill Brook, in the central part of the town, and in 1930 four additional wells were driven and connected with the pump serving the first four. When the auxiliary station is in use, this well water is pumped directly into the distribution mains. The relative quantities of water

*Assistant Engineer, Metcalf and Eddy, Boston, Mass.

† Chase, E. S. Jour. New England Water Works Association, 38: 1, 48, March, 1924.

pumped from the two sources of supply are indicated by the quantities used in the year 1933, when 123 m.g. were pumped from Cape Pond and 7 m.g. from the wells. The auxiliary supply is generally used only between June and October, during which time the wells supply perhaps 10 to 15 per cent. of all the water consumed.

Tastes and Odors in Water. Cape Pond is naturally subject to excessive growths of microscopic organisms, many of which produce objectionable tastes and odors, particularly when they disintegrate in the pipes. This trouble is apt to be most marked during the summer season. It results from the quality of the water, which is high in dissolved organic matter, obtained largely from the swampy areas bordering the pond.

In this pond various types of microörganisms develop at different seasons and in different years. One kind predominates and then disappears, to be followed by another. In recent years the odor-producing organisms of most frequent occurrence appear to have been *Asterionella* and *Tabellaria* of the Diatom group and *Anabaena* of the Cyanophyceae group. *Asterionella* and *Tabellaria* give an aromatic, geranium or fishy odor, depending upon the intensity of occurrence of the organisms. *Anabaena* produces a grassy odor, which is usually accompanied by a moldy odor. When strong, the odor of *Anabaena* resembles that of raw green corn, and in extreme cases it is not unlike that of a pigpen.

At times Cape Pond water has had musty tastes and odors which were not caused by the presence of microscopic organisms. On these occasions the unpleasant effects were probably brought about by decomposition of organic matter at the bottom of the pond, together with the lack of mixing of the top and bottom waters, resulting in stagnant conditions at the lower levels, from which the pumps draw water.

Early in 1922 it was recommended that Cape Pond water be filtered and aërated, in order to improve the quality of the water delivered to the town. Pending the construction of such a purification plant it was recommended that frequent microscopical examinations of the water be made, and that copper sulphate be applied to the pond when such examinations indicated the necessity for action to prevent the excessive growth of microscopic organisms. Accordingly, in 1922, copper sulphate was applied to Cape Pond for the first time, and since then the pond has been treated with this chemical at least once each year.

Method of Applying Copper Sulphate. In applying copper sulphate to Cape Pond, crystals of the chemical are placed in burlap bags, which are tied to the sides of a rowboat and towed through the water until the crystals have dissolved. Fifty pounds of copper sulphate generally are placed in each bag, and two bags are towed through the water at one time. In this manner, 100 lb. of the chemical can usually be applied to the pond in about 20 minutes, although the time required for solution is likely to be increased by low water temperatures, as well as by the use of extra large lumps of copper sulphate and bags which are tightly woven. Reasonable equaliza-

TABLE 1.—RATE AND COST OF COPPER SULPHATE TREATMENT OF CAPE POND, 1922–1934.

Date.	Quantity of Water in Storage (m.g.).	Copper Sulphate Applied.			Cost of Copper Sulphate Treatment.*	
		Lb.	Lb. Per m.g.	P.p.m.	Total.	Per Lb. Applied.
1922, May 22	185	425	2.3	0.3		
May 27	184	920	5.0	0.6		
Nov. 3	166	700	4.2	0.5		
Total		2,045			$160	$0.078
1923, Aug. 14	142	838	5.9	0.7	$ 65	$0.078
1924, Apr. 15	165	960	5.8	0.7		
Sept. 12	157	910	5.8	0.7		
Total		1,870			....	.....
1925, June 8	172	1,000	5.8	0.7		
Sept. 23	138	800	5.8	0.7		
Total		1,800			....	.....
1926, May 26	181	1,050	5.8	0.7		
Oct. 8	138	800	5.8	0.7		
Total		1,850			$115	$0.062
1927, May 27	180	1,043	5.8	0.7		
Oct. 31	164	950	5.8	0.7		
Total		1,993			$135	$0.068
1928, Apr. 11	181	1,050	5.8	0.7		
July 31	176	880	5.0	0.6		
Oct. 25	153	765	5.0	0.6		
Total		2,695			$187	$0.069
1929, July 3	164	950	5.8	0.7		
Sept. 23	129	750	5.8	0.7		
Total		1,700			$128	$0.075
1930, Apr. 11	147	850	5.8	0.7		
July 15	138	800	5.8	0.7		
Nov. 12	95	550	5.8	0.7		
Total		2,200			$170	$0.077

*Exclusive of engineering services and analyses.

TABLE 1.— RATE AND COST OF COPPER SULPHATE TREATMENT OF CAPE POND, 1922–1934 — Continued.

Date.	Quantity of Water in Storage (m.g.).	Copper Sulphate Applied.			Cost of Copper Sulphate Treatment.*	
		Lb.	Lb. Per m.g.	P.p.m.	Total.	Per Lb. Applied.
1931, May 28	181	1,050	5.8	0.7		
June 18	179	750	4.2	0.5		
Nov. 16	147	850	5.8	0.7		
Total		2,650			$174	$0.066
1932, Apr. 4	182	1,050	5.8	0.7		
May 5	178	750	4.2	0.5		
Sept. 27	125	500	4.0	0.5		
Oct. 28	137	600	4.4	0.5		
Total		2,900			$163	$0.056
1933, June 5	178	900	5.1	0.6		
July 24	160	950	5.9	0.7		
Sept. 12	147	900	6.1	0.7		
Total		2,750			$154	$0.056
1934, May 21	178	1,050	5.9	0.7		
Aug. 16	137	800	5.8	0.7		
Total		1,850			$106	$0.057

tion of distribution of the chemical through the water is obtained by guiding the boat on roughly parallel courses around the pond, passing through the deeper portions more frequently than the shallow ones.

The motive power for the boat usually is supplied by two oarsmen. During 1925 and 1926, an outboard motor was used to propel the boat. It was found, however, that the dory owned by the water works, on account of its size and shape, was not well adapted to the use of such a motor.

The quantity of copper sulphate applied to Cape Pond at each treatment has varied from 425 to 1 050 lb., and the dosage has varied from 2.3 to 6.1 lb. per m.g. The rate most frequently employed has been just under 6 lb. per m.g., equivalent to 0.7 p.p.m. (Table 1).

Cost of Copper Sulphate Treatment. During the past 12 years, from one to four copper-sulphate treatments have been administered to Cape Pond each year, the total quantity applied ranging from 838 to 2 900 lb. per year. The annual cost of treatment has varied from a minimum of $65 for a single dose in 1923 to a maximum of $187 for three doses in 1928. The cost of treatment per pound of copper sulphate applied has ranged from a maximum of 7.8 cents in 1922-23 to a minimum of 5.6 cents in 1932-33.

*Exclusive of engineering services and analyses.

These figures include the cost of the chemical delivered at the pond and the cost of labor involved in applying it to the water (Table 1).

Results of Copper Sulphate Treatment. In the first year of treating Cape Pond with copper sulphate, it was learned from microscopical examinations that the action of the chemical in destroying microörganisms is rather slow. Before this fact had been determined, however, considerable numbers of white perch were killed, when two doses of copper sulphate, together amounting to 7.3 lb. per m.g., were applied to the pond in a period of six days.* Since then it has been found that 10 to 18 days generally elapse after treatment of the pond, before the full effect upon the microscopic organisms is observed.

In general, the application of copper sulphate to Cape Pond has been quite successful in preventing the formation of objectionable tastes and odors in the water, by controlling the development of organisms which would cause them. During the past 12½ years, the pond has received 32 doses of this chemical. On 19 of these occasions, reductions of 50 per cent. or more in the numbers of microscopic organisms in the pond water have been effected, some of the reductions running as high as 96 per cent. (Table 2). Nine applications have brought about reductions of 10 to 49 per cent. in numbers of organisms. On the remaining four occasions there has been an actual increase in numbers of organisms present in the pond water, in spite of the copper sulphate treatment. On one of these four occasions, however, the organism *Tabellaria*, which had predominated in the water before treatment, was practically eliminated, being replaced by *Chlamydomonas* of the Protozoa group, which is not so likely to cause unpleasant tastes and odors.

The fact that these four applications, which failed to effect reductions in total numbers of microscopic organisms in the water, have all occurred within the last 3½ years raises the question, whether the continued use of copper sulphate in this pond has not developed a strain of microörganisms which are resistant to the action of copper sulphate. Be that as it may, there is cause for serious doubt that the use of this chemical at Cape Pond in the future will be as successful in preventing objectionable tastes and odors due to microörganisms as it has been in the past.

In view of this doubt, together with the fact that some unpleasant tastes and odors in Cape Pond water have been due to causes other than the development of microörganisms, it appears that the town of Rockport may soon have to face the alternative of either developing an additional ground-water supply, to supplement and dilute the Cape Pond supply, or installing a filter plant, to effect a permanent improvement in the quality of Cape Pond water supplied to consumers.

Acknowledgment. The work of treating the Rockport water supply with copper sulphate has been carried on under the direction of Lewis C. Sanborn, Superintendent of Water Works, with the advice of Metcalf & Eddy.

*Chase, E. S. Jour. New England Water Works Association, 38: 1, 48, March, 1924.

TABLE 2.— RESULTS OF COPPER SULPHATE TREATMENT, As Shown by Numbers of Microscopic Organisms Present in Cape Pond Water, 1922–1934.

Date of Treatment.	Rate of Application of Copper Sulphate (p.p.m.).	Total Number of Organisms per Cubic Centimeter.*		Reduction in Total Organisms, Per cent.	Time of Collection of Samples.	
		Before Treatment.	After Treatment.		No. of Days Before Treatment	No. of Days After Treatment
1922, May 22	0.3	627	267	57	0†	4
May 27	0.6	267	74	72	1	12
Nov. 3	0.5	10,418	2,899	72	0†	13
1923, Aug. 14	0.7	685	323	53	1	15
1924, Apr. 15	0.7	8,720	1,319	85	0†	14
Sept. 12	0.7	4,754	205	96	0†	10
1925, June 8	0.7	2,776	702	74	0†	10
Sept. 23	0.7	3,870	200	95	2	13
1926, May 26	0.7	2,369	245	89	1	14
Oct. 8	0.7	4,740	835	82	3	11
1927, May 27	0.7	7,055	735	90	2	18
Oct. 31	0.7	5,460	1,375	75	0†	16
1928, Apr. 11	0.7	665	598	10	0†	12
July 31	0.6	1,462	1,030	30	1	13
Oct. 25	0.6	2,105	1,738	17	0†	19
1929, July 3	0.7	1,372	388	72	0†	14
Sept. 23	0.7	6,928	1,425	79	0†	17
1930, Apr. 11	0.7	670	460	31	0†	25
July 15	0.7	850	520	39	0†	13
Nov. 12	0.7	4,370	1,139	74	0†	12
1931, May 28	0.7	3,436	4,120	Increase	2	18
June 18	0.5	4,120	150	96	3	11
Nov. 16	0.7	2,521	653	74	4	14
1932, Apr. 4	0.7	1,551	3,910	Increase	6	9
May 5	0.5	11,890	3,760	68	7	11
Sept. 27	0.5	985	630	36	1	8
Oct. 28	0.5	1,185	2,550	Increase	0†	10
1933, June 5	0.6	980‡	688‡	30	5	16
July 24	0.7	1,522‡	990‡	35	7	10
Sept. 12	0.7	1,750‡	1,021‡	42	6	13
1934, May 21	0.7	1,360‡	322‡	76	5	16
Aug. 16	0.7	1,880‡	2,150‡	Increase	3	13

*When more than one sample was collected on any one day, the figure given is the average for all samples collected. Examinations made by Massachusetts Department of Public Health and Metcalf & Eddy.

†"0" indicates that samples were collected on day of treatment, just before treatment was commenced.

‡Standard units per cubic centimeter.

THE BETTERMENT ASSESSMENT METHOD FOR FINANCING WATER MAIN EXTENSIONS.

BY SYDNEY R. WRIGHTINGTON.*

[*Read September 20, 1934.*]

As a town official, I must confess at the start that, as a class, we are inclined to be conservative. We keep on doing things in the way we have been doing them, even after new methods have come to light. That is why Lexington continued its old method of financing water-main extensions for twelve years after the enactment of the General Laws.

Our old method, which we may still employ if we choose, was what we call the method of guaranty bonds, which I think a good many New England towns have adopted. Under it we sought to secure 6 per cent. of the cost of the water-main extension in revenue or in the guaranty payments. Each abutter signed a bond with a surety guaranteeing that the annual revenue from the line for the next ten years would equal 6 per cent. of the cost of construction, and if the value of water sold did not equal this percentage the signers of the bonds would become liable for the difference.

We found various objections to such bonds, and after the decline in real estate values in 1926, and more especially during the present unpleasantness, we began to find the guarantees difficult of enforcement. Town officials are not well qualified to judge the value of personal surety, and we found that the sureties were about in the same condition as some of the principals when we sought to enforce the bonds. I remember one case in which abutter A had endorsed the bond of abutter B, and abutter B had endorsed the bond of abutter A. One of them moved away, and both were insolvent.

Although the bonds in form obligated each signer to pay the whole deficiency, our practice was to divide it among the various signers. When we tried to collect the whole amount from anyone, a question about the interpretation of the bond arose. The fundamental difficulty was that what we were purporting to do was to finance only the interest on the cost. We were not really accomplishing this because a part of the amount was credited to the sale of water. Hence we were receiving compensation for something we were selling. Since we were not supposed to make a profit on the sale of water, we were not financing the principal cost of the improvement.

The selectmen, who in Lexington constitute the Water and Sewer Board, therefore, cast about for some better method of collecting their guaranty bonds. There was some talk about requiring the abutters to sign a mortgage on their property when they signed the bond instead of giving

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a personal surety, but we found so many technical difficulties in the way of this procedure that it was given up.

We were then asked why we did not assess betterments for water mains as we assess them for sewers and highways. There did not seem to be any good reason for not doing this except the tradition that an assessment of a betterment for a water main was considered illegal. That probably had been so prior to the enactment of the General Laws. Betterments had been assessed in Massachusetts at a very early date and the Supreme Court had upheld them. I think the principle was applied more generally in the West, although it gradually came into use in the East, and we did have, as far back as the Revised Laws of 1902, a general law covering betterments in highway construction. But we had a great variety of special acts involving betterments — acts authorizing towns to construct sewers and water systems — and each act had its own special provisions, until the variations became confusing.

Just before the enactment of the General Laws in 1921, a commission was appointed to study the whole question of eminent domain and betterments, and to provide a codification. There resulted Chapters 79 and 80 of the General Laws, Chapter 79 covering eminent domain, and Chapter 80 betterments.

The great accomplishment of the new chapters was a simplification and unification of the method of taking property by eminent domain and the method of assessing betterments. The language of Chapter 80 is much broader than that of any authority for betterments that had existed before. A betterment is now authorized for any public improvement. The words "public improvement" are broad enough to include a water main. In fact, when I began to look into the question, I found that the first case on betterments that was ever carried to the Supreme Court of the United States was a betterment assessed in the District of Columbia for a water main. Although we did not find any Massachusetts decisions, because there had not been, prior to the General Laws, a general authority for water-main betterments, there have been a couple of cases in which the Court has indicated that a betterment for a water main is constitutional.

When we started to assess betterments for water-main extensions, the first obstacle we encountered was our own by-laws which provided that we had to require these guaranty bonds in such cases. This section of the by-laws, was, therefore, amended and it was provided that betterments might be assessed in place of requiring bonds. When we brought the matter before the Assistant Attorney General he very properly said, "When the General Laws give you authority to assess betterments for a water main, you can't do it by by-law." Hence we wrote a section providing that if we did assess betterments we did not have to ask for a guaranty bond. This statement was promptly approved. We published it, and it became a part of our by-laws in 1933. Since then we have assessed betterments, I think, in about a dozen cases.

The procedure in assessing a betterment is fairly simple. The board which is authorized to construct the improvement adopts a formal order. In that order it must recite that betterments are to be assessed for the improvement. The order must include a description sufficiently definite for identification of the area that is determined to be specially benefited by the improvement. The engineer must prepare a plan on which not only the line of the main but the area which is to be benefited are shown. That plan must be referred to in the formal order. If there is any taking by eminent domain, that must also be included in the order. Annexed to it there must be a list of the owners, as of the last assessment date, within the area which is decreed to be benefited. An estimate of the betterment must be listed against those names, and within thirty days the order, with the area and with the plans, must be recorded in the Registry of Deeds. This procedure constitutes a notice to all that a betterment has been assessed on the land under consideration.

Within six months after the work has been completed the board should adopt another order in which it determines the amount of the special benefit to the land which is to be assessed. That betterment must be something more than the general benefit to the community. It must be what the board believes to be the increase in value of the land resulting from the improvement. The board then certifies the betterment to the assessors. The assessors commit it to the collector of taxes and he sends out a notice. If the amount is not paid it is included in the next tax bill. The amount may be apportioned over ten years — it usually is — and the unpaid amount goes on the tax bill in regular order thereafter. Its collection is enforced as a part of the tax. The property may be sold for taxes and foreclosed through the Land Court as in any other tax assessment. The advantages are obvious. There is a perfect security for the claim. It takes precedence over mortgages, and although enforcement is somewhat slow and cumbersome, in the long run payment is assured with adequate interest.

The fact that the assessment is apportioned over ten years, and that it is limited to the amount of the special benefit — I should also have said that it must not be in excess of the estimate which was filed in the Registry of Deeds — make the assessment fair and resonable. That is probably the reason why we have had no trouble, so far, with assessments for water-main extensions. The advantages of this method are such that we are no longer using the guaranty bond, and I believe that before long the bond method will go into the discard.

The great advantage of the new system, to my mind, is that, to a certain extent at least, it constitutes a financing of the capital investment in the water-main extension. The statute contemplates an assessment of the entire cost. Of course it must be limited to the amount of the special benefit — that is, the increase in value — so that as a practical matter it may not be possible to assess the full cost when that seems to be unfair.

In a town like Lexington, with a very large undeveloped area, the need of a more effective method of financing these public improvements is very great. We are likely to be faced with developments somewhat remote from the center. They all require water, they must have it, and the expense to the community becomes great unless those who receive a real increment in the value of their land make a substantial contribution. For that reason we are satisfied with our new method of financing water-main extensions and intend to continue its use.

DISCUSSION.

CHARLES W. SHERMAN.* We have had a somewhat parallel experience in the town of Belmont,— a town immediately adjoining Lexington, which may be of sufficient interest to warrant a description.

Belmont, as compared to Lexington, is a town small in area, and correspondingly a more densely populated town. For quite a number of years practically all of the extensions of water pipes that have been required have been confined to new developments, where real estate promoters have bought up a farm, divided it up and wanted a municipal water supply to assist in selling their lots.

I am not sufficiently posted on the Betterment Act to know whether we could have dealt with the matter, at the time, in the same way as Lexington. The Board of Water Commissioners of Belmont is a separate board from the Selectmen. After three or four years of trying to get along on the old guaranty basis, we finally concluded that as water commissioners the sensible thing for us to do was to tell the real estate promoters that we would deal with them only if they would put the water pipes through their entire development as one job and would meet three-quarters of the cost. We found that under the old system the demand for extensions came practically always after the town meeting was past and funds were not available for the town to make the extensions, also that the expenditure required was such that the bonded investment for the works was running up out of all reason. Consequently, we started in on the new basis I have just described.

MR. WRIGHTINGTON. We have done something quite similar. We have tried in many cases to get the abutters to sign an agreement in advance that they would accept a certain definite estimate as a betterment assessment. They are very eager, in the beginning, to get these improvements and sign the guaranty bonds quite cheerfully. It is only three or four years later, when they have enjoyed the benefit for some time, that they refuse to pay. It is fairly easy to get a promoter to sign. Where we get a large majority of the abutters interested in having an extension, it has been rather easy to get them to sign up a contract under which they will not contest the betterment assessment.

*Of Metcalf and Eddy, Boston, Mass.

ARTHUR C. KING.* I would like to ask Mr. Wrightington a word more about the total amount of the assessment. I understood him to say it was intended to cover the entire cost, but not necessarily.

MR. WRIGHTINGTON. The language of the statute is that the board determines the special benefit and then apportions the cost of the improvement on the land that is specially benefited. It does not say in so many words that it must be the whole cost. Obviously it can't be, because we are limited both by the estimate filed in the Registry of Deeds and by the amount of the special benefit, which is the increase in value; that of course is an intangible thing. It is largely a matter of opinion. I feel sure that the Court will sustain an assessment of a part rather than of the whole, provided it is not done in some arbitrary rule of thumb way and is a determination by the board that the special benefit does not exceed the amount which is assessed.

MR. KING. Could you give any idea as to what proportion of the cost seems to be arrived at as a general average?

MR. WRIGHTINGTON. I do not know how that can be determined. Real estate men are the best judges of that. It would seem to me that the increment of value from the water main is more obvious than it is in the case of any other public improvement. Developers will not start building their houses until they are sure of water. There must be a very definite increase in the value of the land as it is cut up into house lots by the mere fact that water is available, and as the total cost of the extension is much less than the street improvement it must be fairly easy to determine that the special benefit is at least equal to the total cost of the improvement. But there may be cases in which a trunk line is involved in part. In these it would not be fair to assess the whole amount, since one could not say that the entire cost had been added to the value of the lots. It is a little vague and uncertain, and I think that is one reason why people are a little bit afraid of it. The Supreme Court seems to be disposed to back up any administrative board which appears to have acted fairly and with the desire to comply with the statute in making these betterment assessments.

HOWARD M. KING.† Mr. Wrightington, if a 6-in. main passes through the property in one case, and a 12-in. main in another case, do you make the same assessment, or would you base it on actual cost?

MR. WRIGHTINGTON. We have had just that problem. We put in a 12-in. main in one street where a 6-in. main was sufficient to serve the abutters. The 12-in. main was a part of a general connecting link of the water supply which connected two important trunk lines. I understand that the assessment covered only a portion of the cost of the main and and that it was based on what the cost would have been if a 6-in. pipe had been laid. The selectmen must determine that the maximum increase in value is not in excess of the amount assessed. The reasons underlying their determination may become important, and perhaps the value decided upon

*Superintendent, Taunton, Mass. †Superintendent, Springfield, Mass.

could not be expressed in the form of a fraction of the total cost. But as a practical matter that is what it came to in that instance.

WILLIAM NAYLOR.* What would be the attitude of Lexington if a person 2 000 ft. away from an existing main wanted water and none of the other abutters wanted it? That betterment could be assessed upon the other abutters, could it not?

MR. WRIGHTINGTON. It could be, if the extension was made. But it probably would not be made under those circumstances.

MR. NAYLOR. Our method at the present time is to ask the person who wants the water to pay one-half of the expense of a 4-in. pipe.

MR. WRIGHTINGTON. That is where the betterment assessment would equalize the expense. But it is not quite fair to let a man go into a remote part of the town and impose betterments on a lot of people who do not need the improvement, have their own water supply, who are not asking for it, and who might be disposed to contest the betterment assessment. There is no advantage, really, to the town in going to a big expense in extending a trunk line for the benefit of one or two people. So that I assume that if the question were put up to us, the selectmen would refuse to make the extension unless the demand from the intervening region was sufficient to warrant it, or unless there was a very large development at a distance from a trunk line which might justify it.

MR. NAYLOR. This case usually occurs in my experience: Somebody lives two or three thousand feet away from the end of the nearest main, and there are no intervening houses. The land is owned by other people, but the benefit of water ordinarily is not of great value. But this person, who has been supplying himself with an electric pump, perhaps, thinks that the best thing for him to do is to go down and get water from the town, and also to get fire protection. The question is, whether or not we would be justified in asking the other abutters to pay for a betterment.

MR. WRIGHTINGTON. The Supreme Court has said that the mere fact that land is vacant does not prevent you from assessing a betterment. There still may be an increase in the value of the land because of the proximity of the water even though they are not yet ready to use it. There is, therefore, no legal reason so far as betterments in general are concerned, but it would depend upon the amount of the betterment imposed and whether or not experts would say that it caused an increase in value.

CALEB M. SAVILLE.† We have assessed betterments in practically the same way as has been spoken of, except that we limit the size. We can assess up to the estimated cost of an 8-in. main. This theoretically is the smallest size main we put in. In some few cases, where the gridiron is short, we put in 6-in. mains. Usually 8-in. is the smallest size. The estimated cost of the assessment is based on the average cost of laying 8-in. pipes for the last five years. Anything over that estimated cost is borne by the district as a whole. Anything under that cost reverts to the property owner. We

*Maynard, Mass. †Chief Engineer, Hartford Metropolitan District Water Supply, Hartford, Conn.

can only assess up to the cost, and if the cost of an 8-in. pipe is less he gets the benefit of it.

FRANCIS H. KINGSBURY.* I suppose under this proposition there would be an article in the warrant.

MR. WRIGHTINGTON. There does not necessarily have to be an article in the warrant. Before making any appropriation there must be an article in the warrant and a vote must be taken. But it is entirely possible for the town to vote a sum which may be used for water-main extensions, and under our by-law the selectmen are the ones who decide whether or not to make the extension. We have a special town-government scheme there under which all authority is centered in our board of selectmen. They are the water and the sewer commission. They determine under that by-law whether the conditions warrant the extension. They determine whether to call for guaranties or assess a betterment. It is the order of the selectmen which goes into the Registry of Deeds. It is that order, authorizing the construction of the work and the assessment of betterments, which is recorded. If it requires an expenditure by the town — and it always does — there must be an appropriation for it, and ordinarily in Lexington we do have special appropriations for particular extensions. We try to accumulate these before the March meeting and put articles in the warrant covering the various extensions which have been asked for. But as has been suggested, between town meetings a request may be received from an individual. During this last year we had a lump sum in the water department which was used to meet such demands, but ordinarily we refuse to make any extension until the next town meeting.

HUGH MCLEAN.† Some years ago this question was discussed at a meeting of this Association. As a result of the discussion, we adopted the policy of levying a dollar a front foot on the land that was supplied with water. This practice has been successful. Our engineers figured it out that the cost of the extension to a certain tract of land was about $4 a foot. We planned to have the petitioner pay about 50 per cent. and the water department about 50 per cent. We also charged for hydrants put on the line for fire protection.

Only on one particular extension, which was carried through a farm, in the upper part of the city, where there were very few houses, did we require all to sign an agreement to pay the assessment when the water was furnished, and not until then. Some signed up who have not taken water, but still we have their signatures on file. We hold them responsible for their share of the extension, and the property can't be sold to anyone else unless they pay.

HENRY T. GIDLEY.‡ I would like to ask this question: If a man has signed an agreement and has then sold the lot, how can you hold the next owner responsible for the agreement which the first man signed?

*Massachusetts Department of Public Health, Boston, Mass. †Holyoke, Mass. ‡Fairhaven, Mass.

MR. MCLEAN. I think the responsibility runs against the property. We had just such a case a short time ago. The lot was sold and the new buyer of the lot petitioned for water. We obliged him to pay at the rate of a dollar a foot. We had the agreement drawn up and signed by the man and wife, it was on file, and the property was held for it.

THE ACTION OF WATER ON MATERIALS FOR SERVICE PIPES.

BY F. WELLINGTON GILCREAS.*

[*Read September 21, 1934.*]

Service pipes form an important link in water-works plants. Water supplies that are of excellent quality at the pumping station may become unsuitable for use and the source of much complaint because of the action of the water on pipes that have been chosen unwisely. In deciding on the proper kind of service pipes to be used with a given supply, factors such as cost, ease of handling, and so forth are always considered, but often little attention is paid to the possible effect of the water on the materials of which the pipes are made. As a result, the life of the services is short and consumers complain of red water or green water with stains on fixtures, or restricted flow resulting from deposits in the pipes. Because of the importance of these factors in the choice of suitable pipe materials, the action of water will be given chief consideration in the present discussion. The general subject of corrosion is engaging the attention of water-works men at the present time, and our knowledge of the factors involved, chemical and physical, is increasing. However, there is still much that we do not know concerning the effect of substances present in natural and treated waters, in accelerating or retarding corrosive action.

Water Quality. Before selecting the proper service pipe material, each water supply, its chemical composition and particular conditions, should be studied. Experience has taught us that certain factors must be considered if trouble with pipes is to be avoided.

Oxygen concentration, carbon dioxide content, especially as it affects the reaction or pH value of the water, hardness and alkalinity, and dissolved salts are all controlling factors in the possible action of water upon pipe metals. Corrosion requires the presence of oxygen; its concentration often governs the amount of metal dissolved and thus the aggressiveness of a particular water. The presence of acids, such as carbon dioxide, by producing a low pH value, accelerates the corrosive action and in some cases exerts a direct solvent action on certain metals. Soft waters are often more corrosive than hard waters. The presence of calcium carbonate exerts a buffer action and thus prevents low pH values and resulting acceleration of the corrosive action. With hard waters, a precipitation of calcium and magnesium compounds often occurs on the walls of the pipe and thus provides a protective coating to prevent solution of the metal by the water. Large amounts of organic matter in water may play a part in the prevention of corrosion by depositing on the pipes a slimy but protective coating.

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Because water stands in service pipes for long periods, an excellent opportunity is given for the corrosive reactions to take place. Thus velocity of flow does not enter into the problem to the same extent as in distribution mains. Increase in temperature will increase the rate of the chemical actions involved in corrosion.

Lead. Lead has long been a favorite service-pipe metal. However, waters that are soft, colored and of a low pH value, resulting from the presence of carbon dioxide or possibly organic acids, exert a marked solvent action on this metal, often dissolving sufficient lead to be the cause of serious plumbism among the users of the water. Hard waters, or waters with a high pH value, are less aggressive to this metal. When the pH value is about 7.6 and the hardness above 30 p.p.m., little action is ordinarily to be expected. However, in some cases, alkaline waters, that is, those with high pH values, may also dissolve lead.

Zinc. Galvanized iron has also been used extensively for service pipes and, with certain types of waters, successfully. However, waters with a low pH value have a rapid solvent action on zinc and thus expose the iron to the action of the water, with resulting complaints of red water and dirty water and, not uncommonly, disagreeable metallic tastes, due to the presence of large amounts of zinc in the water. Often treatment with lime is resorted to, to prevent solution of the zinc. However, alkaline waters, with a high pH value, that is, greater than 8.4, will also exert a solvent action on zinc, and the trouble instead of being prevented may be continued.

Brass. Brass of varying composition is also widely used for service pipes and under most conditions gives satisfaction. Experience, particularly at Newton, Massachusetts, has shown that waters of moderate hardness, containing carbon dioxide and with resulting low pH value and even with low oxygen concentration, will act on brass to dissolve the zinc, leaving a brittle, honey-combed structure that leaks badly and may collapse without warning. Low carbon dioxide content and high pH values render waters less aggressive to brass. Changes in composition of the brass, with increased copper content, increase the resistance of this metal to corrosion; admiralty metal and red brass are subject to but slight action by the water.

Iron. Water containing dissolved oxygen will corrode iron, with the formation of rust that may appear as dirty or red water or as a deposit in another section of the pipe, clogging it and restricting the flow of water. The extent of the action depends upon the oxygen concentration. Often water low in oxygen will apparently not react on iron, the amount of the metal removed being insignificant. Low pH values accelerate the action of water on iron and, with high values, the action is retarded.

Copper. In recent years, copper as tubing and also as copper pipe has been used more and more for service pipes. However, waters of low pH value and high carbon dioxide content usually act on this metal, dissolving the copper, with resulting complaints of blue or green stains on plumbing fixtures. With higher pH values this action decreases; values of 7.8 or

higher are usually sufficient to reduce the action of the water on the copper to a minimum. Carbon dioxide — rather than oxygen concentration — seems to be the controlling factor in the corrosion of copper. Apparently, the carbon dioxide exerts a direct solvent action on the metal with formation of copper bicarbonate. Under certain conditions of concentration of oxygen and carbon dioxide, very large amounts of copper may be dissolved from copper pipe with resulting serious effects on the taste and appearance of the water.

Pipe Linings. For many years cement-lined pipes have found favor, both for street mains and for service pipes. This lining, of course, protects the metal from the possible action of the water, but under some conditions is itself subject to the action of the constituents of the water. With soft waters containing carbon dioxide, the lime in the cement may be dissolved, thus greatly increasing the hardness of the water and giving rise to complaints. This is particularly true when the pipe is first put into service; as it is used, the action lessens and, finally, as the lime becomes exhausted, water of good quality will be delivered through the pipes. It would seem that often the amount of carbon dioxide present in the water need not be high to react with cement linings.

Various other types of linings have been developed. These are mainly of an inert nature and thus are not subject to the action of the water. There is always, however, the possibility that chlorine used in the treatment of water may react with organic pipe linings to produce serious taste and odor troubles.

Water Treatment. It is thus seen that in choosing the proper materials for service pipes, information as to the composition of the water is most necessary, if corrosion and complaints are to be avoided. Treatment of the water that deposits a protective coating on the pipes as well as removes some of the factors which cause corrosion can be used to prevent or retard this action. For this purpose, lime is probably the best agent, although it has the disadvantage of increasing the hardness of the water and thus introducing another source of consumer complaints. The use of silicate of soda offers possibilities, although it does not seem to have been widely adopted. Soda ash is effective in increasing pH values and removing carbon dioxide, without increased hardness; it is particularly valuable with copper pipe, but no protective coating is formed. Overtreatment with any of these chemicals should be avoided, since alkaline waters may be as aggressive as acid ones toward certain metals, particularly zinc. Aëration will reduce the carbon dioxide content, but by increasing the oxygen content may cause more serious corrosion in other ways.

The problem presented by the choice of proper service pipe material is a complex one. Cost and mechanical suitability are always important. However, the type of water and particularly its pH value and the presence of dissolved oxygen and carbon dioxide must be given careful consideration,

if consumers' complaints are to be avoided and satisfactory water delivered to the taps at all times.

DISCUSSION.

D. A. HEFFERNAN.* When I joined this Association in 1902, one of the main topics was, what material shall we use for services? There was a committee appointed some years ago of which I think the late Mr. Johnson was chairman. Conditions were somewhat different in those days. Lead and galvanized pipe were in general use. Cement-lined pipe, too, had been used for years. The city of Worcester has been using cement-lined pipe for sixty odd years and I have used it for many years and continue to do so. From time to time, there has been an opinion expressed that some other metal, such as brass pipe with a high copper content, could be used to advantage.

There are some elements which I think have been overlooked. Years ago I took up the subject of galvanic action with the late Professor Whipple. I have also made reference to grounding of wires on water pipe resulting in corrosion and discoloration of water. The same condition exists today. Tests have been made which show that grounding of electric light, telephone, or radio wires has affected water. An insulating joint has been put on the service and the trouble from discolored water has been eliminated. I was surprised when a chemist at a winter meeting, brought out the fact that there was a discoloration at his house and followed the trouble to the radio.

Since 1901, when we had some cases of lead poisoning in Milton, cement lined pipe has been used exclusively.

WILLIAM NAYLOR.† May I ask if the water can be treated in such a manner as to be safe for use with galvanized pipe?

MR. GILCREAS. Yes, I think so. Just exactly what the limits are, I would not want to say. But I should imagine that if water was treated to a pH of not over 8.4, and probably not less than 8, there would be little action on the galvanizing. Of course, the difficulty is that the interior zinc lining has often been removed before treatment is instituted. With the use of lime, a protective coating can be produced on the inside of the pipe, and thus a much better chance of using galvanized pipe without trouble is assured. In this case, it is necessary to increase the pH a little more, above 8.4, but the difficulty is that if it goes too high, around 9 or higher, some solvent action on the zinc is exerted.

J. WALTER ACKERMAN.‡ What pH is attained at Albany?

MR. GILCREAS. A pH value of 9.6 has been employed but is now being reduced to 9.0 and less. I do not think there will be as much trouble as before. A great many hot-water systems, using galvanized boilers, gave considerable trouble at the higher pH value. Also, there was trouble with deposits and increased turbidity.

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*Milton, Mass. †Maynard, Mass. ‡Utica, N. Y.

MR. ACKERMAN. I had heard something about the Albany situation. I would like to ask what the distance is from the point of water treatment to the general distribution system and what the pH is when the water arrives there.

MR. GILCREAS. The distance between the point of treatment and the city is approximately 10 miles. The pH which has been carried at the filter plant was about 9.4 or 9.5. There was very little change on the way to the city. At the State Laboratory, we take a sample of the tap water for a check of the pH, and the drop is usually about 0.2 of a pH. Hydrated lime is used to adjust the pH value.

THOMAS E. LALLY.* Are there any ideal limits to the pH value?

MR. GILCREAS. It seems to me very much, Mr. Lally, a case of cut and try. As I said, there seems to be a very small amount of data available on this general subject. There has been a good deal of isolated work done. I have done some myself on certain types of water, and we found by experiment that certain pH values worked well with the conditions existing there. But regarding real, basic data, concerning the effect of the various factors which enter into the action of water on metal, I do not think we have a great deal of information.

Generally speaking, with copper pipe, a pH of about 7.6 to 7.8 is satisfactory. With lead, too, a pH of about that value is satisfactory. If increased higher than that, there is always the danger of sloughing off more lead, and if carried lower, there is the danger that lead will be dissolved as bicarbonate.

To provide a protective coating in distribution mains and service pipes, using lime, the pH value should be maintained between 8.4 and 9.6, that is in the carbonate alkalinity range. The optimum pH depends largely upon other factors such as the concentration of dissolved salts and particularly the hardness of the water.

MR. ACKERMAN. What effect do the higher pH values have upon the application of chlorine and chloramine?

MR. GILCREAS. That is a serious problem. The higher the pH, of course, the less the bactericidal action of chlorine. Very often, a pH of 9.6 will disinfect the water as well as will the addition of chlorine at a lower pH. With the chloramines, it is necessary not to have too high a pH, if we are to have a satisfactory bactericidal effect.

The particular difficulty with the use of lime is that it increases the hardness, thus causing complaints. The industrial value of water so treated is sometimes seriously impaired, especially for boilers, textile plants, and various industries of that nature. Soda ash has certain advantages in not increasing hardness. It has the disadvantage of not producing the protective coating and the further disadvantage, of course, that it costs about twice as much as lime.

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*Boston, Mass.

SAMUEL H. MACKENZIE.* How much action would there be on red brass and copper pipe with the pH running from 6.4 to 6.7? Would there be enough to be detrimental?

MR. GILCREAS. I should not expect much action. To have a decided effect on brass and copper, pH values must be lower than 6.6. Of course, the red brass and metal with high percentage of copper are much more resistant than the old 60–40 brass that was previously used.

LINN H. ENSLOW.† To try to clear up a little confusion about the value of the pH and its effect on stopping corrosion, I think it would be well to point this out: That confusion has arisen largely on account of the varying hardness of the water involved. If a protective coating is to be formed, a bicarbonate alkalinity of 35 p.p.m. must be obtained. Baltimore can get good results with a pH of 6, 7 or 8. In Providence, with a very low alkalinity, values of 9.2 or 9.4 must be reached. That is why chemists find difficulty in answering the questions that are put to us flatly in that way.

RUPERT W. WIGMORE.‡ Our water system at Saint John is not treated. We have lead pipe which has been in service over 85 years. We have never had any lead poisoning, nor discoloration. During the war period, on account of the increased cost of lead, we adopted galvanized pipe for two or three years. The life of that pipe was from six to ten years. It corroded completely in ten years, although previously we had been using a small quantity of galvanized pipe that had been in service about fifteen years. But we have had no trouble whatever with lead pipe.

*Southington, Conn. †Water Works and Sewerage, New York, N. Y. ‡Saint John, N. B.

FREEZING AND THAWING OF WATER MAINS AND SERVICES.

BY ALBERT A. ROSS.*

[*Read September 21, 1934*]

One of the greatest nuisances to property owners and water departments during the winter season is the frozen service pipe or main. Great expense and inconvenience result from this annual hazard, and methods of dealing with freezes and prevention of future trouble are of particular interest to New England Water-works engineers and superintendents.

Since 1900 there have been three winters with abnormally low temperatures and the last one (1933–34) will not be forgotten. During February the average temperature in greater Boston was 17.5° F., which was 11.3° F. below the normal for that month, according to Weather Bureau figures. If we are to experience similar conditions in the future we should be prepared as far as possible in advance by having thawing equipment available, laying mains and service pipes at sufficient depths, and instructing consumers as to the prevention of freezing.

In the town of Lexington most of the trouble during the winter of 1933–34 occurred during February. Although there had been extremely cold weather earlier in the season, the pipes were not affected, due to the fact that the ground was frozen only near the surface. By mid-winter, however, the frost had penetrated to unusual depths, resulting in 137 frozen services, 348 frozen meters and two frozen mains, the sizes of the latter being 6 and 8-in. respectively.

Lexington Water Department. The Lexington Water Department serves a population of 12 000 through 2 656 services. The water system comprises 73 miles of mains varying from 6 to 16-in. in diameter. From the foregoing it can be seen that close to 5.2 per cent. of the services were affected by frost. The town elevation varies from 109 to 380 ft. above sea level, but, apart from customary low winter temperatures, there are no exceptional conditions which the department must face in laying its mains.

Cause of Freezing. It is known that freezing and damage often occur where pipes are too near the surface; when circulation is stopped, or where strains set up during pipe-line installation are increased by freezing of the ground around the pipe. In many cases these strains are incurred by excavations below the pipe, or when new pipe lines or conduits are laid near the old lines. The additional freezing strains are then sufficient to break the pipe.

The 6-in. main which froze was installed in 1902. It had been laid 6 ft. deep in a solid rock trench and was cracked along its entire length. In this

*Superintendent of Water and Sewer Department, Lexington, Mass.

particular case it was necessary to shut off service from 22 families for several hours to make the necessary repairs. Two portable air-compressors mounted on light trucks were used for breaking through the frozen earth, and after repairs to the pipe, the trench was back filled with gravel — not with frozen earth. Both the 8-in. and 6-in. mains were packed in mineral wool after being repaired. The fact that dead ends on mains were bled through small orifices, prevented further trouble with frozen mains.

The majority of the service "freeze-ups" occurred between the sidewalk curb and the main, where snow had been removed to facilitate automobile travel. Whenever a meter froze it was removed for the duration of the cold period and in its place was substituted a nipple.

The depth to which frost will penetrate depends on temperature, soil characteristics, and surface conditions. Penetration is deeper under roadways or pavements, than under sod or loose earth. Consequently, these factors should be considered in laying pipe. Services are laid to a depth of 4 to 5 ft., but changes in street grades reduced the depth of some of the old installations to only 3 or 4 ft. During the summer of 1934, all these shallow services have been lowered to 6 ft. and we intend that all future installations including mains, shall be at depths of 6 ft., as a precaution against possible severe weather.

Service Crews. Three crews of four men each were on duty thawing out services. One crew handled our portable electric unit capable of producing 200 amp. at 11 volts on 25 cycle alternating current. For longer and larger services outside the range of this unit, it was necessary to hire a larger 12-k.w. machine capable of producing 50 to 400 amp. with voltages varying from 5 to 60. This generator was driven by a 38-h.p. motor and was manned by the second crew. The third crew was in charge of a mounted steam boiler which operated at 25 to 100 lb. per sq. in. gage.

Electric Thawing. Because electricity provides a cheaper and quicker means for thawing frozen pipes than the other methods now in use, it is becoming a favorite method, although it seems to have some limitations. When thawing ice-filled pipes electrically, the heat generated by the flow of current through the pipe melts the ice inside. No two pipes have the same resistance, even though they are the same length and diameter. The contacts established, and the joints, have an important bearing on the resistance encountered. Generally speaking, electric thawing should not be attempted with contact wires smaller than 000 (three naught). Waterworks men generally have found that the time required to thaw by electricity varies from 3 minutes to 4 hours. Pipe resistance and likelihood of soil conductivity, inducing current to leave the line are among the variable factors accounting for the great difference in time required. My experience has been with intervals between five minutes and 1½ hours, depending on the length of the service and general conditions.

In one particular instance electricity was carried through 160 ft. of 6-in. pipe laid in 1929, the pipe having compound joints. Contacts for the

apparatus were made between service connections in the cellars of two houses in the neighborhood. (A method often employed is to connect between a hydrant and a service connection.) In the case of the 8-in. main referred to previously, an unsuccessful attempt was made to thaw it by electricity. This pipe had been laid with compound joints in 1932. It is apparent that installations having compound joints tend to become better conductors as they get older.

Other Thawing Methods. In order to restore the flow in the 8-in. main, it was necessary to open sections about 200 ft. apart and to thaw by steam which was admitted through the corporation cock. In a number of cases it was possible to thaw several services at one time where the houses were close together. Eight blowoffs, located at various points in the system were partly opened and kept running during the severest cold period. Where hydrants froze, carbide in lump form was inserted through the steamer nozzle.

In the case of copper services, of which we have a few, it was necessary to thaw them with hot water, or steam, since the metal offered little resistance to electric current. In a number of cases where galvanized-iron services were frozen in passing through the cellar wall, a large gasoline torch was found to be effective for thawing. Wherever goosenecks froze it was necessary to excavate at the corporation cock. Due to the high velocity of the water and the expansion of the ice, tubercles were released, resulting in complaints from various sections of the town. The situation was remedied by complete flushing of the system. Other complaints were received as to the taste of the water, following electrical thawing. It is believed the unpleasant taste was caused by the overheating of the compound joint which gave the water a sulphur taste.

Precautions. With regard to precautions to prevent freezing, as far as possible, we feel the responsibility rests jointly on the water department and the consumer. Certain methods that we use in the Lexington Department, such as service crews, hydrant inspection and proper depth for pipe, have been described. Before the consumer can do his part, he is entitled to receive instructions. Last winter we made a practice of enclosing an instruction-card with our bills, describing simple precautions that the customer should take to prevent freezing. When a continuously running faucet caused higher than average charges, special allowances were made. This year we expect to continue the notices, but it is doubtful if allowances will be made. Although it had been customary to make a charge for frozen services and meters previous to last year, at that time, due to the unusual condition, the Board of Selectmen voted not to make the charge.

This paper covers the main points of our problem of 1933–34 and indicates briefly what we have in mind for the future.

Discussion.

Howard M. King.* Do I understand that one of your frozen mains was an 8-in. main?

Mr. Ross. Yes. This main happened to be in a section of our distribution system where there was no circulation. The break occurred at 4 o'clock in the morning, and I personally was on the job and took particular pains to measure the depth of the trench. It was a 6-ft. cut in shale. The main was practically a dead end, with only a few services beyond the break. This fact may explain the freezing.

Mr. King. At Springfield three hydrant connections which were below the frost line snapped off crosswise; one 6-in. main also broke.

Mr. Ross. We had four hydrants that cracked due to freezing.

D. A. Heffernan.† In Milton no mains were frozen, and only a few services. We have a pretty good cover on our pipe, 4 ft. 10 in. The frost went down below that. We use compound joints entirely. I cannot see why, if the pipe is laid properly, contact between pipes should not be established, that is, if the pipe is pushed home. On straight lines this is a simple matter on curves it may be difficult to secure contact.

William F. Sullivan.‡ Our instructions to the foremen and workmen are to push the pipe home, but men are fallible. I do not know what effect a ½-in. or ¼-in. space between bell and spigot, might have in opposing current flow.

Frank J. Gifford.§ In this matter of pipes being pushed home, there is always the criticism that the men do not carry out their work properly. But there is another angle to the matter, it seems to me: the irregular edges at the end of the pipe. We might not have a cleancut spigot end. I believe that is well illustrated when, in electric thawing, you first get contact through a line and then suddenly lose it. I think that is due to the melting of the edge through the arc that is formed. An arc is produced and then the compound joint is melted out. Last summer, leaks in the system we found to be due to the disintegration of metal at compound joints by arcing. These failures may have been due to lack of pressing the pipe home, or to the irregularities of the spigot ends of the pipe having been burned off.

John H. Read.** There is another element besides that touched upon by Mr. Gifford which should be given due consideration. That is the fact that pipe is coated with a very effective insulator. Even if pipe laying is well done, the bell is coated and together with a composition joint forms a mighty good insulator. In addition, pipe is usually laid in summer and troubles occur in winter. A few thousandths of an inch of clearance by contraction due to low temperatures may make it impossible to thaw pipes with low voltages.

One day we had what appeared to be a routine leak report. Our emergency man who had attempted to dig the joint up, sent in a hurry call

*Springfield, Mass. †Milton, Mass. ‡Nashua, N. H. §Dedham, Mass. **Manchester, N. H.

that the joint was on fire. An electric current, not connected with thawing operations, was working through the pipe. The composition joint was actually blazing a bluish flame, with a sulphurous smoke, so that you could not get anywhere near the pit.

The current was attempting to jump across the face of the joint, and in doing so, arced across. The potential was much higher than that used in thawing by electricity.

J. P. MILLER.* We had difficulty thawing compound-joint pipe at North Adams. We had been using compound joints for about seven years. Quite a number of water mains froze during the winter of 1933–34. We tried to thaw out these mains with electricity but we could not get any current through them. We had to cut a section out of the line and thawed the line with steam. One 10-in. line was frozen for about 100 ft., where it passed underneath a dry brook. The pipe was thawed with steam. Over 1 000 ft. of pipe, from 4 to 10-in. in diameter was frozen; also approximately a thousand services. Some of these were frozen three or four times. One 6-in. bridge crossing that had been repaired by welding was permitted to discharge through two 1-in. streams all one night, but both the pipe and the two 1-in. streams froze. In regard to electrical thawing machines, we had two outfits equipped with transformers and one that was an electric welding machine. The transformers required 2 200 volts. In districts without this primary voltage, we used the electric welding machine. I think from our experience that the electric welding machine is the better machine. I noticed that when we used the 2 200-volt current in our transformers there were more apt to be ruptures of the mains and of the service pipes than when we used the electric welding machine.

MR. GIFFORD. I see Mr. Wigmore from New Brunswick here, and I am tempted to ask him not for his solution, but to see whether or not he would agree that, rather than laying pipe at greater depths, a good snowstorm early in the winter would be desirable providing all the snowplows were kept off the road.

RUPERT W. WIGMORE.† I agree with that. We had no difficulty with frozen mains until recent years, when snow was plowed off the streets. On back streets where snow is not cleared to the pavement, or the roadway, we have had no trouble with freeze-ups.

We have a daily inspection of hydrants during cold weather. The city is divided into zones, and in those different zones a man visits each hydrant every day and drops his rod in to see if there is any frost at the bottom. During the winter of 1933–34 we had difficulty with freezing between the main and the hydrant. In order to discover frozen sections of this type, the inspector carried a piece of hose with him long enough to reach from the hydrant to a catch basin. He could then open the hydrant and let the water flow into the sewer. In this way a frozen lead could be discovered.

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*North Adams, Mass. †Saint John, N. B.

PERCY A. SHAW.* With reference to thawing copper services by electricity, our experience has been that they take a little more current and time than do iron pipes. If an iron pipe thaws in five minutes, copper pipe may take ten or twelve minutes. The only part of the service we have not been able to thaw out electrically is the lead gooseneck. We had to take out quite a number of those.

DONALD C. CALDERWOOD.† In Nashua a number of services were thawed by tapping the regular high tension wire of the power company. We did a little experimenting together with the power company. They took a regular transformer for household service that had been damaged (the coil had been burned out). This little instrument weighed in the vicinity of 100 lb. We thawed several services with it, using 110-volt current. It was attached to the regular light service for the house, in back of the meter, and we made it a rule not to draw more than 40 amperes from the service. In doing so, 100 volts at 40 amperes represented about 4 000 watts; retransformed to 10 volts gave 400 amperes. Even 200 amperes will do a fairly good job on a short service. I think many of the water departments, if they wished to go into it, could either purchase or rent an instrument similar to this one, and by working in conjunction with the local electric light or power company they could have a little portable unit for thawing services. I would not attempt to do too much of a job on a main of any sort with this device, but would use it for thawing services.

ANTHONY C. BENJES.‡ In the winter of 1933–34 we were thawing pipes continuously for about a month. The power company provided a 25 kw. transformer on a service truck, and a 50-gal. hogshead containing a salt solution. Drawing 110 volts from the main power line, we had no trouble at all in thawing as much as 160 ft. of copper service pipe. We had to use a large wire to do it.

*Manchester, N. H. †Nashua, N. H. ‡Lebanon, N. H.

ROADSIDE WATER SUPPLIES.

BY ELMER W. CAMPBELL.*

[*Read December 20, 1934.*]

Most states exercise some supervision over roadside water supplies but the method of supervising them naturally varies considerably. The State of Maine, being a popular summer resort visited by many thousands of people, both tourists and those who come to stay for the entire summer, early began supervision of water supplies located along the highways.

In 1927, the Maine Legislature set up a license law requiring the licensing of all types of roadside eating places, roadside lodging places or tourist homes, motor camps or overnight camps as they are called, and recreational camps which include juvenile camps, adult camps, camps devoted to both adults and children, and hunting and fishing camps. Owing to the fact that license requirements cover so many types of establishments the data which I will present will necessarily include each variety of place as well as the ordinary roadside establishments. However, these have been sub-divided and tabulated in such a manner that I think it will be relatively easy to distinguish the different types of water supplies.

We may assume that the overnight camps and the eating and lodging places are nearly all located along the highways, and their water supplies may well be considered of the roadside variety. The recreational camps are largely situated off the main highways and their supplies could hardly be classified under the definition of roadside supplies.

When the license law went into effect we immediately established an inspection service. Since that time, before a license was issued, we have required a complete inspection of the premises. Inspections include among other things a description of the sources of water supply. If a municipal water system is used, that fact is noted. If the establishment maintains its own private water system a complete description of it is made. If the source of supply is a well or a spring, the type of well or spring is described, the method of covering it, the manner in which the water is drawn and similar information. If the construction of the walls or cover of the well or spring is faulty, that fact is noted, and the owner is instructed in proper methods of making repairs so as adequately to protect the water from external pollution. Many hundreds of dug wells and springs have been lined with concrete or tile and supplied with water-tight cement covers. In many cases drilled wells, or as they are frequently called, artesian wells, have been developed both to secure additional volumes of water and also to provide an acceptable quality of water.

One of the definite requirements for a license is that a safe water supply shall be provided for those persons who patronize the establishments.

*Director, Division of Sanitary Engineering, Maine State Bureau of Health, Augusta, Me.

If it is impossible to secure a safe and adequate water supply on the premises owing to local conditions of contamination or for other causes, the proprietor is required to transport water for domestic use from some satisfactory supply. This usually means securing water from either a municipal system or from a commercial spring-water company. This is rather an inconvenience to the proprietor and when required to bring water from distant places provides a great inducement to develop a new supply as near as possible to the place of business.

In the vicinity of the cities this policy has resulted in the extension of city water mains in some instances for miles, providing additional income to the water utility concerned. This is notably true in the southern part of the state between Portland and Kittery. The city water is now carried the entire distance between Portland and Biddeford, both systems having extended their lines to the limits of their districts. The towns of Kennebunk and York have likewise extended their lines materially. As a result of these extensions many wells and springs which were formerly used and which were unsafe and not of satisfactory quality to be dispensed to the public were eliminated.

In Maine practically all the roadside water supplies are connected with or situated on the premises of some licensed eating or lodging place, and there are very few roadside supplies, such as springs or wells, that are available to the public but not under supervision. There may be a few isolated ones on infrequently traveled roads but on the main roads they are practically non-existent.

The year 1927 was the first during which information on roadside water supplies was collected. During that year 1 762 water supplies were investigated. Of these 10.3 per cent. were found to be unsatisfactory and considered unsafe because of inadequate protection or because they were shown to contain bacteria of the colon-aerogenes group or the presence of excessive amounts of organic substances that indicated underground contamination with drainage from sources of pollution, such as cesspools, leaky sewers, stables and privies. These unsafe supplies were all barred from use, and the owners were directed to make corrections or to secure safe sources of supply immediately.

During the second year, the number of places investigated was materially greater, namely 2 552. Of these 10.8 per cent. were found to be unsatisfactory, showing a slight increase in the percentage of unsatisfactory water supplies, but among a very much larger number of places investigated. The increase may readily be explained by the rapid expansion of roadside business which brought new supplies under our supervision for the first time. As we all know this was in the period of expansion and relatively easy money, and the tourist business and summer resort business were rapidly increasing along with other lines of endeavor.

The effect of our investigations and recommendations began to be felt by the end of the third year. Although 3 051 water supplies were investi-

TABLE 1.— WATER SUPPLIES FOR LICENSED RECREATIONAL CAMPS, TOURISTS' EATING AND LODGING PLACES AND OVER-NIGHT CAMPS. Division of Sanitary Engineering, Maine State Bureau of Health, 1927–1933.

	NUMBER OF SAFE SUPPLIES.							NUMBER OF UNSAFE SUPPLIES.						
Eating Places	**1927**	**1928**	**1929**	**1930**	**1931**	**1932**	**1933**	**1927**	**1928**	**1929**	**1930**	**1931**	**1932**	**1933**
1. Municipal Supplies	311	495	602	691	753	704	697	0	0	0	0	0	0	0
2. Dug Wells	197	305	380	446	354	311	129	72	105	100	80	58	33	32
3. Springs	184	264	314	396	331	301	261	27	34	30	17	18	18	22
4. Drilled Wells	33	51	52	77	79	56	133	0	9	12	6	7	7	15
5. Lakes or Ponds	0	5	8	11	8	8	9	0	0	0	2	1	1	38
6. Rivers or Streams	2	1	1	1	0	1	0	0	0	0	0	0	0	0
Lodging Places														
1. Municipal Supplies	152	305	356	429	1196	1264	1115	0	0	0	0	0	0	0
2. Dug Wells	90	142	163	231	254	230	157	26	51	56	34	38	20	21
3. Springs	85	121	149	169	229	191	183	5	15	8	5	8	14	15
4. Drilled Wells	10	28	36	54	73	58	115	0	1	6	1	2	2	10
5. Lakes or Ponds	0	3	3	3	12	0	7	0	0	0	0	0	0	1
6. Rivers or Streams	2	1	1	0	0	2	0	1	0	0	0	0	0	0
Over-night Camps														
1. Municipal Supplies	86	107	137	179	219	248	245	0	0	0	0	0	0	0
2. Dug Wells	49	63	95	120	142	161	84	11	17	7	17	23	12	15
3. Springs	49	68	89	104	132	135	110	0	15	5	3	8	6	12
4. Drilled Wells	9	17	23	30	37	30	75	0	4	2	3	2	0	6
5. Lakes or Ponds	1	3	7	2	5	2	3	1	0	2	0	0	0	2
6. Rivers or Streams	1	0	1	2	0	1	0	0	0	0	1	2	0	0
Recreational Camps														
1. Municipal Supplies	23	22	33	31	37	33	36	0	0	0	0	0	0	0
2. Dug Wells	69	71	95	117	99	127	81	12	12	9	18	6	10	17
3. Springs	190	153	171	219	230	200	195	15	11	24	16	17	13	21
4. Drilled Wells	32	28	31	33	49	43	76	1	0	2	3	3	1	3
5. Lakes or Ponds	14	21	31	14	10	19	19	1	2	2	4	1	3	1
6. Rivers or Streams	1	2	5	4	5	4	3	0	0	1	4	0	0	0
TOTALS	1590	2276	2783	3363	4254	4129	3733	172	276	268	214	194	140	196

TABLE 2. — DISTRIBUTION OF LICENSES ISSUED.

Maine State Bureau of Health, Division of Sanitary Engineering, 1927–1934.

License Year.	Total Licenses Issued.	Eating Places.	Lodging Places.	Overnight Camps.	Recreational Camps.
1927–28	2197	1059	458	250	430
28–29	3054	1562	745	314	433
29–30	3430	1704	843	400	483
30–31	3791	1886	944	474	487
31–32	4621	1747	1819	573	482
32–33	4477	1581	1820	604	472
33–34	4164	1445	1661	578	480
34–35	4272	1376	1824	592	480

TABLE 3.— WATER SUPPLIES FOR RECREATIONAL CAMPS, TOURISTS' EATING AND LODGING PLACES AND OVER-NIGHT CAMPS.

Maine State Bureau of Health, Division of Sanitary Engineering, 1927–1934.

License Year.	Total Water Supplies Tested.	Number of Safe Supplies.	Number of Unsafe Supplies.
1927–28	1770	1587	183
28–29	2552	2276	276
29–30	3051	2783	268
30–31	3577	3363	214
31–32	4448	4254	194
32–33	4269	4129	140
33–34	3929	3733	196
34–35	4051	3871	180

TABLE 4.— RELATIONSHIP BETWEEN THE INCREASE IN LICENSES ISSUED AND UNSATISFACTORY WATER SUPPLIES.

Maine State Bureau of Health, Division of Sanitary Engineering, 1927–1934.

License Year.	Licenses Issued.	Per cent. Increase in Licenses.	Per cent. Unsatisfactory Water Supplies.
1927–28	2200	0	10.3
28–29	3054	32	10.8
29–30	3430	56	8.8
30–31	3791	72	6.0
31–32	4621	111	4.3
32–33	4477	103	3.3
33–34	4164	89	4.9
34–35	4272	94	4.4

gated, the percentage of unsatisfactory water supplied dropped to 8.8 per cent. This gave us great encouragement and was followed by a further, reduction in percentage of impure water supplies in the following year with a material increase in places investigated. The number of supplies was 3 577 and the percentage of unsatisfactory water 6.0 per cent. The year 1931 was undoubtedly the peak or banner year. A total of 4 448 places was investigated of which only 4.3 per cent. showed unsatisfactory water.

In 1932 we began to feel the effects of the depression. A considerable number of places failed to open or closed their doors for lack of patronage. Of 4 269 places investigated, 3.3 per cent. showed unsatisfactory water supplies.

Even if there had not been our requirement that those establishments showing unsatisfactory water supplies must secure water for their patrons from an approved source or if because of negligence or lack of coöperation they had failed to follow instructions, the greatest possible chance for the traveler receiving impure water from any place where he might stop was only about one in thirty-two. This is a record which even the municipal water systems of the average state will consider very good and something worth attaining, the figures in all instances being based upon the results of laboratory analysis supported by inspection data.

In order to make this information available for comparisons I have prepared tables 1 to 4 which show the sources of water supplies for licensed eating places, lodging places, over-night camps and recreational camps. By studying these tables one can readily determine just how many of each class of water supply were investigated and how many of each type were found to be safe or unsafe.

It is our view-point that all roadside water supplies made accessible to the public should be so maintained and so supervised that they will be safe and not likely at any time to cause illness to the consumer and that all unsafe water supplies shall be definitely abandoned and made inaccessible to the public.

SLOW SAND FILTRATION PLANT, NEWBURYPORT, MASS.

BY PAUL F. HOWARD.*

[*Read December 20, 1934.*]

The City of Newburyport, Mass. is a typical old New England community which due to its good harbor facilities at the mouth of the Merrimac River formerly enjoyed the advantages common to such seaports. Today, however, it is mainly a manufacturing community with shoe factories and silversmiths predominant.

Population. As indicated in the following tabulation the population increase of Newburyport has been very slight, and there seems to be no good reason to expect that it will increase much faster in the future. Therefore, there is not likely to be a noticeable increased demand for water unless manufacturing plants requiring considerable water should locate in Newburyport. The city and federal censuses show the population as follows:

Year.	Population.
1900	14 478
1905	14 675
1910	14 949
1915	15 311
1920	15 618
1925	15 656
1930	15 084

Water Consumption. The water consumption has not increased during the past five years as is indicated by the following summary:

WATER CONSUMPTION IN GALLONS.

Year.	Average Daily Consumption.	Maximum Daily Consumption.	Average Daily Consumption Per Capita.
1929	1 398 000	1 827 000	92
1930	1 304 000	1 822 000	86
1931	1 271 000	1 716 300	84
1932	1 318 000	2 005 500	87
1933	1 220 000	1 769 200	81

These water consumption figures are not high when it is considered that only about 12 per cent. of the water furnished to the consumers is metered.

WATER SUPPLY AND QUALITY.

Artichoke Supply. About 60 per cent. of the total amount of water consumed, or 770 000 g.p.d., is furnished from reservoirs on the Artichoke

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River located partly in the town of West Newbury and the city of Newburyport and is derived from a water shed of about 6 sq. miles. While the population on the water shed of the Artichoke River above the water-works intake is not large, there are 70 dwellings, farms, etc. located in this area which are all possible sources of pollution. The water from these reservoirs is highly colored, has an appreciable content of organic matter and plankton growths as well as bacteria characteristic of pollution, and requires considerable treatment to render it odorless, colorless and of safe sanitary quality. Most of the color and organic matter and some of the plankton growths are attributable to the swamp lands around the shores and at the head of the reservoirs and to the lower shallow reservoir itself.

The Massachusetts Department of Public Health in its annual report for the year 1930, comparing this surface water supply with others in Massachusetts, reported the albuminoid ammonia content of the water from these reservoirs to be 0.309 p.p.m. and higher than that in any other supply in the State. It was also reported that this water had an average color of 37 p.p.m., and that there were 168 surface-water supplies which had less color while 12 had more.

The water in the Artichoke Reservoirs supports characteristic vegetable growths which impart to the water odors that range in intensity from very faint to distinct and unpleasant. Analyses made during the year 1933 show that the iron content of this reservoir water averaged 0.4 p.p.m. and varied from 0.18 to 0.82 p.p.m. These values are higher than desirable for a domestic water supply.

As stated, the results of bacteriological examinations of this supply showed that the number and kinds of bacteria present in it rendered it unsafe for human consumption without adequate treatment.

Supply from Wells and Springs. The water from the first supply in the vicinity of the main pumping station is taken from three large covered dug wells, from several pipe wells which overflow and from several springs which out-crop in this vicinity. About 40 per cent. of the total water pumped, or 530 000 g.p.d., is obtained from these wells and springs. The water from the pipe wells, one dug well and most of the springs has a very high iron content, and iron precipitates on the ground and edges of the collecting basin where the water from these springs and pipe wells flows over the surface. The iron content of these wells and springs varies from 0.10 to 1.1 p.p.m. and averages about 0.5 p.p.m. This supply was not filtered.

Bacteriological analyses showed that the water from the combined wells and springs also was not safe for human consumption unless adequately purified.

Old Filtration Plant. The old works provided for pumping the water from the Artichoke Reservoirs through about 2 miles of 6-in. and 12-in. mains to three slow sand-filter areas which discharged into the collecting

basin at the main pumping station. The water was pumped into the distribution system directly from the collecting basin.

The Jackman filter was an open filter with earth embankments and some underdrains which discharged over the surface of the ground into the main collecting basin.

The covered filter had earth embankments and a wooden roof much like the old covered bridge at Newburyport.

The Moulton filter was open and had concrete walls and bottom and an underdrainage system of tile pipe which discharged directly into the large collecting basin. The walls were 6 ft. 6 in. high and averaged 2 ft. in thickness, while the floor had a thickness of 5 in. These filters were all filled to a depth of about 4 ft. with local sand and gravel taken from nearby pits.

General Design of New Filtration Plant.

Selection of Type of Filter. In February, 1933 the author's firm submitted a report to the city of Newburyport and recommended that slow sand-filters be constructed. Although the tendency, during recent years, has been to build rapid sand-filter plants, it was decided to construct a slow sand-filter plant as it seemed to have many advantages in this case. Since the supply is divided between a ground-water supply and a surface-water supply and since both waters needed to be filtered in order to be made safe for domestic use, it was felt that there would be some difficulty in securing proper coagulation of this mixture of waters, varying at times from 40 to 100 per cent. of ground water, unless an experienced chemist was employed to operate the plant.

It was determined that a substantial proportion of the expense of constructing a slow sand-filter plant could be saved by using the then existing concrete walls and bottom of the Moulton filter. Studies also showed that sufficient color removal could be obtained by the use of slow sand-filters without the aid of chemicals, and that such filters also would remove a large percentage of the iron present in the ground-water supply.

The unemployment problem had been acute in Newburyport, and it was felt that a much larger percentage of the cost of constructing the filter plant could be used in the employment of local labor if a filter of the slow sand type was built. Also there had been a strong desire expressed by the water takers of Newburyport to do away with the practice of chlorinating the water. It was felt that chlorination might still be necessary if a rapid sand-filter plant was built but might not be necessary with a slow sand-filter plant.

Filter. The design provided for dividing the Moulton filter into four equal parts by means of concrete walls and then covering them with concrete of groined-arch construction. Over these arches were placed 2 ft. of earth and loam. Each of the four filter units has a net sand area of 6 700 sq. ft. and a total capacity of 500 000 g.p.d. when filtering at a rate of

3 250 000 g.p.d. per acre, making a total daily capacity of the four units of 2 000 000 g.p.d.

Based on the general average conditions of water consumption of the last few years, it is estimated that it will be necessary to operate the filters at a rate of only 2 100 000 g.p.d. per acre, except when one unit is being raked or cleaned. The average daily rate for the other three filters will then be 2 800 000 g.p.d. per acre. These low rates of filtration were adopted in order to secure a greater removal of color, taste and odor.

Emergency Supply. On May 18, 1934 at the time of the Merrimac Street conflagration there were pumped into the city 2 247 000 gal. of water. This water was pumped from the large collecting reservoir near the main pumping station directly into the distribution system without being filtered, although it was chlorinated. The present works are so designed that during any emergency water may again be pumped, after chlorination, directly into the distribution system in the same manner.

Gate House. A gate house was built at the southeasterly side of the present Moulton filter. This building is partly underground and is about 27 ft. long and 22 ft. wide and has a wooden pitched roof. In this gate house are four individual automatic Simplex rate-of-flow controllers of the scale-arm type together with the necessary piping arrangements to control the flow onto and from the filters. Electric lights are installed in the filter units and the gate house, and manholes are placed in the tops of the filters.

Filtered Water Basin. A filtered- or clear-water basin equal in size to one of the filter units with a capacity of 500 000 gal. is built just north of the filters. The roof of the basin is constructed of concrete of the groined-arch design, except that the outer surface is finished to an even sloping plane. This basin is also covered with 2 ft. of earth and loam. The water flows by gravity through a 12-in. cement-lined cast-iron pipe from the filters to the clear-water basin and then to the large pumps at the pumping station.

Aërators. The filters and clear-water basin have been so located that if at any time it should be deemed advisable to secure a further removal of taste and odor by aëration either before or after filtration, this may be readily done without additional pumping.

Construction and Details of New Filtration Plant.

Preliminary Work. The proposed layout, plans and report were submitted to the State Department of Public Health, and on March 16, 1933 this department agreed that if these improvements were made and the filters constructed these filters would "if properly managed and maintained, successfully remove the present objectionable conditions of the water supply of the City of Newburyport."

Detail plans were immediately prepared, and a program of construction was arranged in order to be ready when the city would vote to go ahead. It was shortly after this time that the National Industrial Recovery Act

was born, and applications were drawn up promptly and presented to the Massachusetts Emergency Finance Board on about August 1, 1933. This was the first step towards getting approval for Federal aid. Also at this time bids were received by the Board of Water Commissioners for furnishing wooden forms for concrete, cement, special cast-iron fittings, rate-of-flow controllers, crushed stone, vitrified channel pipe, gate valves, etc. In general, everything was done that would prepare the way so that there would be no delay after the city received approval from Washington. On August 30, a hearing was held before the State Emergency Finance Board, and the project was approved a few days later.

On October 4, 1933, the application for this project, including its construction by force account or day labor, was approved and on the following day actual construction in the field was commenced. This was one of the first Public Works Administration jobs in the Commonwealth of Massachusetts and was one of the few that was carried out entirely by force account or day work. It was the first water-works project to be started under the Public Works Administration in this state.

The Public Works Administration regulations allowed only a thirty-hour labor week; so the work was arranged in two shifts, each gang working five hours a day for six days. This gave a sixty-hour working week with fresh labor every five hours. This arrangement worked out very well as the majority of the workmen were former factory employees not skilled in this type of labor and easily tired.

The first operation consisted of removing the sand from the existing Moulton filter. This was done by means of scoops, wheel-barrows and teams. It was desired to make the entire construction primarily a labor project, and in general machinery was not used. Work started with about forty men on each shift, or a total of eighty men, and about thirteen pairs of horses. Unfortunately for them, the horses did not come under the Public Works Administration restrictions and had to work their full ten hours each day although the drivers were changed every five hours.

There were about 4 ft. of sand in the existing filter, and this was removed and dumped adjacent to the work to be later used as backfill over and about the new construction. The existing underdrains were carefully removed and salvaged for other use in the city. Excavations were also made for the foundation of the gate house, for the clear water basin and for the inlet and discharge piping.

Concrete Construction. The new concrete floor and the bases of the columns of the new filter were poured following the removal of the sand. This work was begun on October 18, 1933.

Detailed plans had previously been completed and contracts awarded for construction of complete wooden forms for the floor, columns and roof. These forms came in sections which were readily handled and could be easily placed by the men on the work. Enough forms were made to complete one filter unit. The clear-water basin was made of a size similar to one

of the filter units so as to be able to use the same forms. All the forms, therefore, were used five times over.

Floor forms for one complete unit were first laid in one section of the proposed filters, and alternate squares of concrete were poured. After the concrete had set the forms were removed and the remaining sections poured using the existing sections for the forms. Key-ways were put in the edge of each square and painted with heavy asphalt previous to the pouring of the remainder of the floor. The column bases were poured at the same time as the alternate sections of the floor, and short steel dowels were placed in them

FIG. 1.— ROOF FORMS.

to insure proper bond with the columns. The bases of the columns were built with a batter so that it was necessary to hold the forms down with sand bags to keep them from rising out of position when they were filled with concrete. Provision to do this had been made in the forms by extending the braces at the bottom.

The forms for the side and center walls were made in panels and were each used several times. Alternate sections of these walls were poured and the intervening gap was filled after the joints had been well painted with an asphaltic preparation to take care of expansion. The column bases were used as anchors against which to brace the forms.

Following the completion of the walls, the roof and column forms were placed. The roof forms had been made in advance according to detailed plans and templates. They consisted of stringers placed about 6 in. apart and covered with ¼-in. commercial ply board. These forms came in sections of a size convenient for two men to handle, and eight of them made a complete groined arch. These sections were bolted together in place, carefully marked and were used five times, only a small amount of patching being necessary. (See Fig. 1.)

The concrete above these forms was made 6 in. thick over the top of the arch and about 18 in. thick over the columns. Drainage of the low points over the columns was taken care of by placing 1½-in. copper tubes through the concrete and surrounding them on the outside with gravel so that water would be conducted into the filter. One roof section was left out of each filter unit so that the forms could be taken down and removed through this opening to the next unit.

A minimum of 6 in. of concrete was placed on the old floor. The new floor varied in thickness from 6 in. at the valleys to 15 in. below the columns. The column bases are 24 in. square, 24 in. high and have a batter of 2 in. The columns are 16 in. square, 6 ft. 1 in. high above the base, and are spaced 12 ft. 2 in. on centers. Each filter unit is about 96 ft. by 71 ft. in the clear and has 35 columns supporting the roof. The groined arch roof has a rise of 2 ft. 2 in. between columns. The interior, or cross walls are 28 in. thick at the base, 16 in. thick at the top with a total height of 8 ft. 1 in. The side walls were made by adding 8 in. of concrete to the inside face of the existing walls and continuing the total width to the same height as that of the columns and cross walls. Due to the fact that the old filter was out of square additional concrete was added to the walls to make the new work rectangular, thus enabling the city to use the same standard forms for roof and floor. The concrete proportions used were 1:2:4 except for the additional concrete poured to square up the walls, when the proportions were 1:3:6, and for the floor of the clear-water basin where a denser mix of 1:2½:3¼ was used to insure water tightness.

The walls of the clear-water basin have a thickness of 24 in. at the base and 18 in. at the top and a height of 8 ft. 1 in., the remainder of the construction being similar to each filter unit. An underfloor of concrete 1 in. thick was first placed in the clear-water basin to make a smooth surface for the floor forms.

No steel reinforcing was used except for new concrete added to the existing walls and a small amount for the roof.

Gasoline concrete-mixers were rented from local merchants and used in mild weather. In cold weather a mixer operated by a steam engine was employed. During freezing weather, extreme care was taken to protect the concrete, and the sand and stone were placed over perforated pipes which were connected to the steam boiler. Heat was maintained throughout the night so that the sand and stone would not freeze. The water was kept well heated by a steam line connected with the boiler. No quick-setting cements, calcium or admixtures of any kind were used. After being poured, the concrete in the interior and side walls was protected by thick layers of salt hay placed on both sides and over the top of the forms. After the walls had been poured and the roof forms had been set in place, several furnaces were constructed inside the units and kept heated day and night. After pouring the concrete of the roof, salt hay was placed on top to a thickness of about 2 ft., and there was no difficulty in keeping the concrete from freezing. Salt

hay was found to be very satisfactory. The concrete was warm to the touch several days after pouring. The hay remained moist and when carefully piled could be used indefinitely, only the outer portion showing any sign of freezing.

The critical test came on February 8, 1934, when concrete was poured during most of the day with the temperature at about zero, while throughout the following night and the early morning of February 9, the thermometer went down to 20 degrees Fahrenheit below zero. Concrete was poured again on the following day with the temperature remaining at zero. The concrete was carefully examined after the forms and salt hay had been removed, and no bad results of any kind were found.

Underdrains, Inlets, etc. After the concrete had been completed and all forms stripped, the snow, ice and débris were removed and the filters cleaned. Underdrains were then placed in each filter. These consisted of 12-in. split-tile drain or channel pipe. The underdrains were spaced about 12 ft. apart and were connected to brick collecting drains, these in turn were connected to cast-iron pipes which led to the gate house. It was decided to use brick collecting drains so as to be able to readily connect the split tile underdrains into them and to give more manual labor. The collecting drains were made of brick work 8 in. thick and possessed a clear opening of about 12 in. by 18 in.

Inlet chambers of brick were constructed in each filter unit about 3 ft. by 10 ft. in plan and about 4 ft. high. The top 12 in. of these inlets were laid with loose brick so that they could be removed as the height of the sand diminished. The intention is to have the water flow smoothly on to the sand and thus prevent sand disturbance which will occur if the inlet chamber is higher than the sand. Allowance was made for 4 ft. 3 in. of water above the sand, and overflow pipes were placed in each filter.

Provisions were made for the future removal of dirty sand by means of sand ejectors. The necessary underground piping was laid and openings were left in the walls to permit the connection of sand piping.

Filter Gravel and Sand. After the underdrains had been placed, they were carefully covered with washed gravel of graded sizes. Seven inches of gravel from 2 in. to ¾ in. in size were first placed over the laterals; then 3 in. of gravel ¾ to ¼ in. in size; and finally 2 in. of gravel ¼ in. to 12 in. size mesh. This made a total thickness of 12 in. and covered a width of about 8 ft. Upon the gravel were placed 3 ft. 6 in. of carefully selected Plum Island sand of an effective size of 0.40 m.m. and a uniformity coefficient of 2.0 m.m.

Explorations were made at several sites on Plum Island, and samples of sand were taken and examined in order to obtain a grade suitable for filtration. A particular sand dune was finally picked out analysis of which had shown it to be of a proper uniformity and size. This sand dune was owned by the town of Newbury which was glad to give it to the city of Newburyport because removal of the sand created a convenient parking

area in the town of Newbury. The excavation of this sand was all done by hand labor using about 70 men to load about 20 trucks.

The roadway into the bank was made of old forms that had been used for the concrete. Trucks hauling about 2½ cu. yd. were backed into the bank and were loaded at the rate of one every three minutes continually over the eight-hour day. The distance from Plum Island to the filters is about 7 miles and sufficient trucks were used so that there was no delay or waiting. At the filters the sand was dumped from the trucks through man-

FIG. 2.— INTERIOR OF GATE HOUSE.

hole openings and carefully placed to a minimum depth of 3 ft. 9 in. Composite samples of sand were taken every day for analysis as to effective size and uniformity.

Controllers and Gages. The piping in the gate house is so arranged that the filters can be filled from below with filtered water. On each discharge is placed a Simplex rate-of-flow controller with 8-in. straight through outlets, a normal capacity of 500 000 g.p.d. with a corresponding loss of head of 1 ft., and a maximum capacity of 750 000 g.p.d. with a corresponding loss of head of 2.1 ft. Loss-of-head gages made of U tubes and connected with the suction and discharge piping are placed on the wall of the gate house. (See Fig. 2.)

It was deemed desirable to have gages showing the heights of the water in the filters and clear-water basin installed on the wall of the main pumping

station which is about 800 ft. away from the filters. It was also necessary that means be taken to keep the gate house warm during the winter weather. These two requirements were accomplished by laying a line of 12-in. split-tile pipe, containing both the steam and gage lines, from the main pumping station to the gate house. The trench was first excavated to careful line and grade, and in it was placed the bottom section of the split tile. Steel rods supporting rollers were then secured to this tile by means of mortar. A steam-pipe line was connected from the boiler at the pumping station, laid on these rollers and connected with the radiator at the gate house. Expansion sleeves were put in every 150 ft. to take care of temperature

FIG. 3.— GATE HOUSE AND COVERED FILTER.

changes. There were also placed in this pipe five copper tubes connecting each filter and the clear water basin with the gage board at the pumping station. The steam pipe was covered with a light grade of asbestos which was sufficient protection to carry enough heat to the radiator and which also gave off enough heat to keep the water in the copper tubes from freezing. The upper half of the tile pipe was then placed and the joints cemented. This pipe was all laid to careful grade so that any condensation or any leakage would flow to a low point and be carried away by drains.

The gages at the pumping station showing the heights of water were made of glass U tubes filled with mercury.

Grading. The sand and gravel which had been removed from the original Moulton filter were placed on the roof of the new filters to a depth of 2 ft. On the top and side slopes, sod was placed which was taken from city land at the Artichoke Reservoirs. (See Fig. 3.)

Pumps. Under the old arrangement, water from the Artichoke Reservoirs was lifted by means of electrically driven Triplex pumps onto the filters and then flowed by gravity to the main collecting basin where it

mingled with the supply from the springs and wells. From this collecting basin the mixed water was pumped into the distribution system by either an Allis Chalmers or a Laidlaw cross-compound Corliss engine and duplex double acting pump.

Under the new arrangements, water is still pumped directly onto the filters from the Artichoke Reservoirs. The water from the wells and springs, however, is pumped from the collecting basin onto the filters by means of a new steam-engine-driven centrifugal pump. The mixed water flows by gravity from the filters to the clear-water basin and thence to the large distribution-system steam pumps.

The original plans to pump water from the collecting basin to the filters called for a 500 g.p.m. motor-driven centrifugal pump. A careful analysis of costs showed that a steam-engine-driven pump could be installed at a cost which would be favorable to the city. Although the first cost would be considerably more, the increased cost of coal consumed versus the cost of electricity was so much less that over a period of years it would be more profitable to install the steam-engine-driven pump. Bids were received for such an installation, and the contract awarded for the installation of a Manistee centrifugal pump driven by an Ames Unaflow engine.

It was found that the exhaust steam of the Unaflow engine could be used to raise the temperature of the water returning to the boilers from the large steam engines about 100° F. and thus increase materially the overall plant efficiency.

The pump under average or usual conditions has a speed of 1 000 r.p.m. and a capacity of 1 050 g.p.m. against a total head of 50 ft. It has a capacity of 1 400 g.p.m. at a speed of 1 180 r.p.m. These variations in quantities are accomplished by changing the speed of the engine. This pump is connected with a flexible coupling to a single-reduction horizontal gear-unit with a ratio of 6.93:1. The speed gear is connected in turn to the engine by a standard type forged-steel flexible coupling.

The engine is an Ames 13 in. by 14 in. horizontal, two valve, true Unaflow type designed to operate with 100 lb. per sq. in. initial pressure and atmospheric exhaust. The engine can be operated at any speed up to 300 r.p.m. and with a rating up to 90 i.h.p. This engine is of such a size that a generator may be readily connected to it. This may ultimately be done to furnish light and power to the main pumping station and possibly to the Artichoke Pumping Station. In fact, the shaft which connects the engine and the speed gear has been made of proper length with key way so that it may be easily connected to a generator.

A horizontal feed-water heater of four-pass construction with U tubes was installed and arranged with two sections, one for heating the boiler feed-water to a temperature of 210° F. with steam at atmospheric pressure; the other section to be used for condensing any surplus exhaust steam with city water.

A water ejector was installed to prime the centrifugal pump.

Incidental Work. Additional work not originally contemplated was carried on with Civil Works Administration and Emergency Relief Administration funds. Some of this work included the replacing of about 500 ft. of 6-in. water main with 12-in. pipe, the erection of a large shed suitable for storing pipe, tools, etc., extra grading in the vicinity of the filters and clear-water basin, street drainage and gutter work, the removal of the wooden roof of the old covered filter, etc.

Results of Operation. Filtered water was first delivered to the distribution system during the latter part of October, 1934 but was still chlorinated. The State Department of Public Health made several analyses of the filtered water during November and found it free from bacteria characteristic of pollution and safe for drinking without chlorination. On December 6, 1934, chlorination was discontinued. Analyses also made at this time showed the color content to be greatly reduced, the Artichoke water before filtration having a color of 45 p.p.m. while the mixed filtered water had a color of only 13 p.p.m.

Up to May 1, 1935, the filter has removed from the applied raw water all odor; 55 per cent. of the coloring matter; 66 per cent. of the organic matter determined as albuminoid ammonia and 75 per cent. of the iron. That is, the effluent has been odorless at all times, with a color of 9 and an iron content of 0.09 p.p.m.

Cost of Construction. The total amount of money received from all sources and spent on or in the vicinity of this project amounted to $125 000. Of this total, $54 000 was donated by the Federal Government through the Public Works Administration, Civil Works Administration and Emergency Relief Administration. The balance of $71 000 was the total cost to the city of Newburyport. This amount of $125 000 was expended as follows:

$ 35 000	for labor under P.W.A.
34 000	for labor under C.W.A. and E.R.A.
36 000	for materials purchased from merchants in the city and nearby communities.
20 000	for materials and services secured outside the city.
$125 000	Total.

It is interesting to note that about 55 per cent. of the entire sum was paid for labor to the citizens of Newburyport and that $105 000 was spent locally for labor and materials. A further advantage was received by the city through the employment of laborers who worked out their overdue water bills.

Personnel. The grants from the Federal Government were promptly secured by Gayden W. Morrill, Mayor and C. F. A. Hall, M.D., Chairman of the Water Board.

The filtration plant was designed and its execution supervised by Whitman & Howard, Engineers — Paul F. Howard, Sanitary Engineer and C. Roger Pearson, Supervising Engineer.

James H. Ronan, superintendent of streets, ably served as construction superintendent.

Valuable assistance, both in construction and in dealing with the Federal authorities, was furnished by Henry V. Macksey, engineer-inspector for the Public Works Administration, a former president of the NEW ENGLAND WATER WORKS ASSOCIATION.

RESPONSIBILITY OF WATER UTILITIES FOR COLLAPSE OF HOT WATER BOILERS RESULTING FROM PRESSURE DROP IN MAIN.

BY WILLIAM F. SULLIVAN.*

[*Read September 21, 1934.*]

Is a Water Works liable for damages when a hot water boiler collapses? That is the question. Collapses are infrequent and the financial loss small, but when they occur they become moot questions of responsibility.

This subject has been chosen for discussion in an endeavor to place the blame for such mishaps. These occasional happenings would be of minor importance, were it not that they annoy the water takers who are victims of this avoidable type of accident.

For a water works to pay damage when it is neither morally nor legally responsible is wrong in principle and is sure to establish a bad precedent. The direct cause of this type of failure is associated with interruptions of every-day service. Such interruptions cannot be entirely avoided. A main pipe may break. Necessary repairs and extensions on a system must be made and while work is in progress the water must be shut off and pipe lines drained. Even a closed service pipe or the changing of a meter may produce a collapsed boiler.

When a boiler collapses the owner naturally blames the water works. The water works has its own version of the trouble and denies liability. Then who is to be blamed for the collapse? Should the complaint be against the water works for shutting off the water or should the makers of boilers who sell tanks that have the habit of collapsing be held responsible?

Plumbers, to gain an advantage over a competitor, may install low-priced jobs sometimes with and sometimes without the knowledge of the owner. Such plumbers make failures possible and bring discomfiture to their customers. Owners may know they are buying cheap boilers without realizing the chance consequences.

To my mind the chief offenders are the few, so-called, reputable manufacturers who sell an article that they know will not stand the test which daily service demands. Hot-water boilers that are capable of resisting all interior strains should stand, at least, an exterior pressure of one-tenth the interior pressure. Purchasers take it for granted that all hot-water boilers are strong enough to withstand the very limited atmospheric pressure exerted when only a partial vacuum is created. Most of them assume that the installation is "fool proof." Stability of cheap boilers is not certain even when they are provided with the so-called "vent." Tests show that 6-in. of vacuum will collapse some guaranteed boilers.

* President, Pennichuck Water Works, Nashua, N. H.

The percentage of failures is so small, that someone might argue that, as a whole, it is good economics to keep the aggregate investment in boilers low by using inexpensive types. Try that reasoning on an angry customer and escape.

The fact that some makers place tags on boilers warning buyers that unless a relief valve is provided the warranty is not good, is an admission that the boiler is weak in a most essential feature. Flimsy materials and workmanship which will cause boilers to fold up like a bellows when sub-

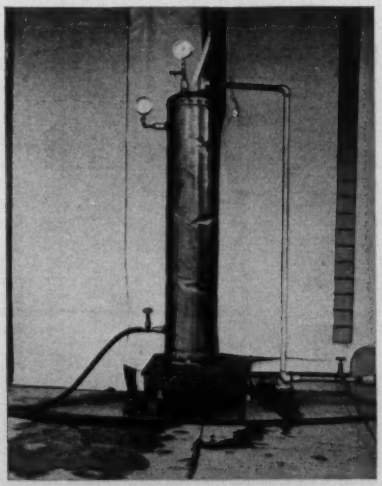

FIG. 1.— BOILER AT START OF TEST.

Crimps are due to collapsing the tank in a preliminary test. The water pressure is 60 lb. per sq. in., and the capacity of the boiler is 25 gal.

jected to an external pressure as low as 4 lb. per sq. in. is nothing short of imposition on the public buying hot-water boilers.

A further question arises: — If a water works is liable for such a fixture why not be responsible for all water-connected fixtures on the premises? When an interruption in water service is known to occur, owners and occupants of buildings are usually notified of the shut-off. This motion does not prevent collapses. It is anything but amusing to a housewife in the kitchen to be startled by a crinkling noise and see her pride, the bright copper cylinder shrinking and crumpling in a most uncanny manner. To say the least, it must be mildly terrifying to her and later astonishing to see

the wrecked boiler balloon out when the pressure is applied, look whole again and function as before all this mystery occurred.

While testing a so-called guaranteed boiler it was funny to see it breathe and behave like an accordian. We have satisfied ourselves that boiler collapses are due to insufficiency of materials. We are convinced that boilers should be designed to meet all the working conditions to which they are subjected and particularly to strains produced by a vacuum.

Massachusetts has building codes, plumbing ordinances and regulations which protect the owners as well as compelling them to install proper fixtures. Boilers provided with temperature, pressure and vacuum relief

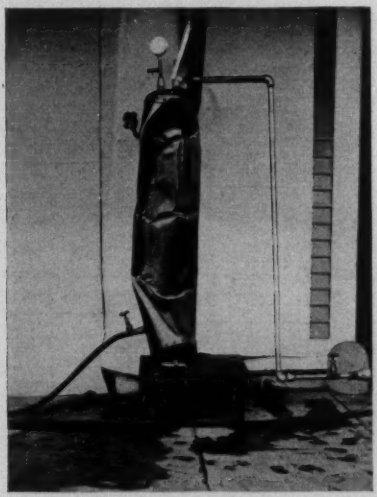

FIG. 2.— BOILER AFTER WITHDRAWING 17¾ GAL. UNDER A VACUUM OF 29 IN. OF MERCURY.

valves are reasonably free from failure. A peculiar thing about these boiler accidents is that while in a collapsed state the boiler appears worthless. Presto, when the pressure returns, they fill out, and the sum total of damages consists of a few wrinkles; the boiler becomes immediately usable again. If not paid for by the water works, such boilers continue in service indefinitely with no apparent weakness.

To maintain happy public relations, a water works is sometimes prompted to purchase these trick boilers instead of adopting the principle of paying an outright claim and leaving the boiler to the owner to repeat its pranks. Such purchases are generally few, and the boilers can be installed

in buildings of the water works. This method is only an expedient to prevent entanglements or avoid a nuisance suit. Usually we are positive and say we are not responsible. It should be clear that the collapse of hot water boilers should be treated the same as the failure of any other water fixture on a customer's premises whether properly or improperly installed. In my opinion there can be no just claim against water works for collapsible boilers.

Mr. Calderwood made a test on a boiler purchased from a water taker and installed in a water works building. The results are illustrated in Figures 1 to 3.

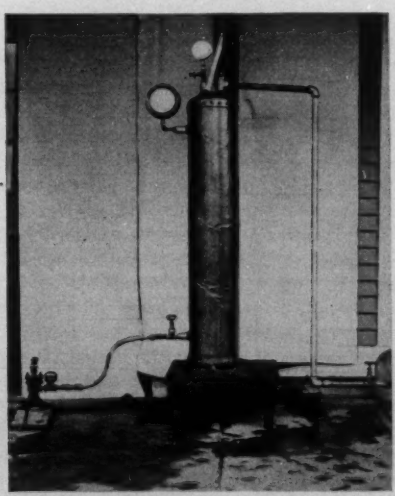

FIG. 3.— BOILER AFTER REFILLING WITH WATER UNDER A PRESSURE OF 140 LB. PER SQ. IN.

As we know, most makers put on the market a boiler that will stand all the conditions of service. Such boilers are tested for 200 lb. per sq. in. internal pressure. But sad to relate some of them will collapse under a few pounds of atmospheric pressure. Examination of this kind of boiler shows it has neither sufficient thickness, nor stays or braces; when water is quickly drawn off it collapses.

A repair man changing a meter in the cellar is confronted by an irate occupant of the house with "What have you done to my hot-water boiler?" He completes his job, turns on the water, goes upstairs and to the amazement of the householder the tank is there looking and working as usual.

Discussion.

David A. Heffernan.* I would like to ask if the boiler that was tested leaked after being restored to its original shape?

Mr. Sullivan. No. Strange as it may appear, our experience has been that nothing really happens to impair the boilers' usefulness. In shutting off water on a main line it is only seldom that a boiler collapses on the whole line. Why do 99 per cent. of the boilers withstand all the vacuum tests?

The head of a large water works stated to me, "we never have a collapsed boiler, and it is simply because the owners do not install low-priced boilers."

J. H. Read.† Was the boiler tested equipped with a cold-water delivery tube?

Mr. Sullivan. Yes, a $\frac{1}{16}$-in. vent. I would like someone to tell me how effective a $\frac{1}{16}$-in. vent is in breaking a sudden vacuum.

Donald C. Calderwood.‡ There are times when the collapse of a boiler is not connected with operations of the water works. A few days ago when I was in a wholesale plumbing shop the talk drifted to copper boilers and one of the employees told me the following story:

It seemed that in a certain two-tenement house, cheap copper boilers had been installed and to the piping at the bottom of each boiler was connected a drain pipe that was piped to a faucet located in the cellar. The faucet was leaking and the owner, attempting to be his own plumber, shut off the water, opened the faucet and started to repack it. His wife called to him from upstairs and asked him what he was doing, that the tanks had been pulled out of shape. Investigating, he found the tanks in both apartments partially collapsed, so he immediately turned on the water and the tanks resumed the original shape. About two years later the tanks started to leak, so he went back to the wholesale house and entered a complaint, claiming that the tanks were defective. At the time the tanks collapsed, however, he had told what had happened and so no adjustment was made.

Mr. Heffernan. The Milton regulations state that the town is not responsible for any damaged boilers. Where it is possible, we notify the consumers in the section to be shut down. Of course that is not practical if we have a break. Our notice reads as follows:

This is to notify you that on.....at.....M. the water supply will be temporarily shut off from your premises for about..... hours for the purpose of making repairs to the water mains.

Hot water boilers are of two types: supplied either direct from street water pressure or from a tank located in the upper part of the building. In case yours is of the type first mentioned you are advised to extinguish the fire under the boiler and open a hot water faucet, even though the system be equipped with the customary vacuum, relief and/or temperature valves. Failure to follow this advice may result in damage to person and property.

*Milton, Mass. †Manchester, N. H. ‡Nashua, N. H.

I quote from the bulletin of a manufacturer of vacuum relief valve.

All of the range boilers and automatic heaters illustrated in this bulletin . . . are manufactured under the very carefully developed requirements of the Massachusetts Range Boiler Law. In fact, this so-called Massachusetts Standard is accepted practically everywhere as being the best measure of tests in boiler construction. Under these standards the use of boilers is permitted on a working pressure not exceeding 42½ per cent of the test pressure. . . . The testing pressures and working pressures of these range boilers are: 200-lb. test pressure for 85-lb. working pressure, 250-lb. test pressure for 106-lb. working pressure, and 350-lb. test pressure for 148-lb. working pressure (Massachusetts Standard).

In Milton, when a pressure boiler is installed, the inspector of plumbing determines the water pressure.

In regard to responsibility, several cases came before the Commissioners where people wanted to collect damages. Their attention was drawn to the fact that the rules and regulations of the department provide that the town is not responsible for damage to boilers.

The workings of these relief valves are not positive. They cannot be depended upon at all times. Boilers equipped with the necessary vacuum-relief valves do collapse. Failure of the valve to function is not a responsibility of the water department. The Milton Water Department took the necessary precaution to put that in their regulations, and should not be responsible for damage if the boiler collapses.

There is a boiler now on the market on which there is a 20-year guarantee. It is non-collapsible. I tried to get a demonstration of that boiler for this meeting but could not arrange it. There are also some copper boilers which will stand up when the vacuum valve fails to operate.

SIDNEY S. ANTHONY.* Have you a standard practice for installing relief valves?

MR. HEFFERNAN. They can be installed on top of the boiler or at the sink. It is a good plan to have the relief valve discharge into the sink.

* Augusta, Me.

COMPLETING SECOND 48-INCH FORCE MAIN, NEW BEDFORD, MASS.*

BY STEPHEN H. TAYLOR.†

[*Read March 21, 1935.*]

The so-called "Further Water Supply" system of New Bedford was constructed during the period from 1895 to 1899 and put into service in July of the latter year. This system is described in some detail in a paper by the author published in the JOURNAL of this Association.‡ One of its most important parts was a 48-in. rivetted-steel force main $\frac{5}{16}$-in. thick, coated by dipping in California asphalt. The line is 8 miles long and through it is delivered water from the pumping station on Quittacas Pond in Rochester to High Hill Distributing Reservoir in Dartmouth. From this point the city is supplied by gravity. At the time of its construction, steel was chosen for this force main because of its considerably lower cost over cast iron. For many years the supply to the city depended entirely on this force main and on sufficient storage of water in High Hill Reservoir to supply the consumption for 10 days or two weeks. Occasional inspections of the condition of the interior of this steel main showed that considerable tuberculation and pitting were taking place. No evidence of external corrosion has ever been found.

In 1921, it was deemed wise, on account of the internal pitting, to make provision for a second method of supplying the city with water in case of failure of this steel force main. Another reason for this decision was the fact that by this time the consumption of water had about doubled so that the storage in the reservoir was sufficient to supply the city only for about one week. Plans were accordingly made and bonds issued for laying a second 48-in. force main of cast-iron pipe from the pumping station to Middleboro Road, a distance of 12 016 ft. and thence southerly in Middleboro Road and Acushnet Ave. 6 609 ft. to the city line where the main connected to the distribution system; thus affording a means of pumping directly into the distributing system with the reservoir acting as a balance. The section from the pumping station to Middleboro Road was laid in the 5 rod strip of land purchased for the original steel force main, 25 ft. distant from that main. The other section was laid in the highway.

At various intervals of time from 1921 until 1932, this second force main was extended in the same strip of land with the original main as far as Braley's Station, a total length of a little over four miles. Cast-iron pipe was used for this entire length. The last 9 000 ft. of this pipe were lined with Bitumastic enamel, centrifugally applied at the foundry. This left a little

*See also two following papers in this JOURNAL.

†Superintendent, Water Department, New Bedford, Mass.

‡Vol. 36, No. 3.

less than four miles or about 19 000 ft. of pipe to complete the second line to High Hill Reservoir.

On the passage of the National Recovery Act of June 1933, it was decided to apply for a loan and grant of funds for the completion of this second main.

To relate the various delays and annoyances in getting action from the various State and Federal officials on granting the petition and prosecuting the work would be much too tiresome for writer or reader; so I will try to summarize as briefly as possible.

To begin with, the data which had to be submitted with the petition comprised a complete history of the city and everybody connected with it and made up a large volume when completed. This volume was brought together and submitted to the State Emergency Finance Board in September, 1933. From there it went to the Federal Administrator, Federal Emergency Administration for Public Works through the State Advisory Board at Boston and was approved by Washington authorities on December 15, 1933. A much longer time would probably have elapsed had not the Mayor of New Bedford gone to Washington and spent about a week chasing this and other projects for New Bedford through the maze of red tape in which they were entangled. The original application was based on the use of cast-iron pipe laid under force account and called for a loan and grant agreement in the total amount of $500 000.

In January, 1934, the Water Board after hearing the advantages of Lock Joint Pipe outlined decided to receive alternate bids on this ype of pipe, and after still further consideration on February 26th, it was decided to prepare specifications on three alternates, viz: —

1. 48-in. Cast Iron pipe, under either NEW ENGLAND WATER WORKS ASSOCIATION or Hi-tensile specifications, with spun bitumastic enamel lining.
2. 48-in. Welded Steel pipe, $\frac{5}{16}$-in. thick with spun bitumastic enamel lining and covered with bituminous enamel and felt, to be connected by Dresser couplings or their equivalent.
3. Steel-cylinder reinforced-concrete pipe.

It was still intended to lay the pipe under force account. Because of objections on the part of the State Engineer on the ground that the cost of laying the three types of pipe under force account would not be the same, it finally became necessary to formulate new specifications based on the same three types of pipe laid under contract, still leaving the connection with High Hill Reservoir, about 100 ft., to be done under force account with cast-iron pipe.

About this time it was found that the city could issue bonds for this work more advantageously without Federal Government aid. The original agreement based on loan and grant was, therefore, cancelled and a new agreement was made, based on grant only and contract instead of force account for the greater part of the job.

This new agreement was completed on April 27, 1934. Specifications, based on the same three types of pipe furnished and laid under contract, were prepared and after several interviews and much correspondence with the State Engineer's office were finally approved by him. Bids were opened on June 5, 1934, as follows: —

PRICES PER LINEAR FOOT FOR FURNISHING AND LAYING COMPLETE

No.	Cast Iron. N.E.W.W.A.	Cast Iron. Hi-Tens.	Welded Steel.	Reinforced Concrete.	Total Amount of Bid.
1	....	....	....	10.90	$207 100*
2	....	....	11.70	....	222 300*
3	....	....	12.98	....	246 620*
4	....	....	13.08	....	248 520
5	....	....	13.25	....	251 750
6	....	....	....	13.30	252 700
7	....	....	13.50	....	256 500
8	....	....	14.50	....	275 500
9	....	....	14.54	....	276 260
10	....	....	15.29	....	290 510
11a	22.50	....	....	....	427 500
11b	....	20.75	....	....	394 250
11c	....	....	17.25	....	327 750

* Three lowest bidders.

The bid submitted for furnishing and laying cast-iron pipe plus the cost of the part done under force account compares very closely with our estimated cost of doing the work under force account. This estimate was based on the cost of that part of the second line constructed by our own forces in the past.

On June 6, the Water Board awarded the contract to the low bidder, the Lock Joint Pipe Co. of Ampere, N. J. This award was approved by the State Engineer on June 13.

Under the terms of the contract, the pipe was manufactured at one end of the work and distributed by trucks along the line. The manufacturing plant and delivery were operated under the pipe manufacturer's code, and the laying was under Public Works Administration regulations.

The manufacturing plant arrived about July 1, and by the middle of the month it was completely set up and turning out regularly twenty-four 12-ft. lengths of 48-in. pipe per day, in accordance with original expectations. Pipe manufacturing proceeded with remarkable regularity until early in November when a sufficient number of pipes had been made to complete the job.

Pipe laying started on August 16, and was completed on November 19. The entire job including backfilling, grading, etc. was completed about the middle of December. The work proceeded with remarkable regularity and efficiency.

Acceptance tests showed the line to be remarkably tight. Tests were made in two sections; the first being 10 883 ft. and the second 7 851 ft. long.

Tests were made in the presence of representatives of the contractor, the city and the Federal Government inspector. Test pressure was maintained by means of a triplex displacement pump working through a 1-in. metered connection with by-pass through which water not needed to replace leakage was wasted. The meter was carefully tested in our meter department before and after making the acceptance test, and we are sure of its accuracy. I mention this because the results obtained seem too good to be true; but every precaution was taken to insure accuracy.

The first or upper section was filled only one day before the test was recorded. This allowed a rather short time for complete absorption of water by the concrete and elimination of air pockets. The section was filled from the top. This, we all know, is the wrong way to fill a pipe, as air pockets are almost sure to occur. Under the circumstances, however, it was the only practical way. The section was tested at a pressure of 50 lb. per sq. in. To maintain this pressure for one hour, required the addition of 3.3 cu. ft. of water. This indicates a leakage of 321 gal. per mile per day as compared with the allowable 6 000 gal. Stated in another way, the leakage was 7 gal. per inch-mile as compared with 125 gal. allowed by the specifications.

The second, or lower, section was properly filled from the lower end about five days before the recorded test, and I believe this test is much more representative than the first. This section was tested at a pressure of 102 lb. per sq. in. To maintain this pressure for one hour, required the addition of 0.11 cu. ft. of water, indicating a leakage of 13.2 gal. per mile per day or 0.28 gal. per inch-mile. Another indication of the tightness of this second section is the fact that while the pressure was being built up, the pump was stopped for a period of 16 hours over night. During this period, the bottled-in pressure dropped from 78 to 70 lb. per sq. in.; still 20 lb. per sq. in. above reservoir pressure. In other words, with no make up, the bottled-in pressure dropped only 8 lb. during 16 hours in 7 851 ft. of 48-in. pipe.

The city furnished the necessary check, gate, air and blow-off valves, culvert extensions and valve chambers. We also made the connection to High Hill Reservoir and with the 36-in. by-pass line on the east side of the reservoir.

When the pipe was filled, it was sterilized by the use of chlorine gas. The Massachusetts Department of Public Health kindly furnished the apparatus and an operator for applying the chlorine.

Plans and specifications were prepared by the regular forces of the Water Department. No charge for these engineering features appears in the costs given, as these expenditures were absorbed by our regular budget account. Lines and grades were given by the employees of the City Engineering Department. Inspection was provided by one man at the pipe-manufacturing plant and another on the pipe line. The latter was one of our regularly employed sub-foremen who was completely familiar with pipe laying. The cost of the two latter items is included in the figures given.

The Lock Joint Pipe Company carried on the work in a very satisfactory manner and with excellent coöperation between their representatives, our own staff and the Public Works Administration resident inspector who was present for the entire duration of the job. Their whole endeavor was to provide the best possible job, and the tests show that they succeeded remarkably well.

The cost of the job was as follows: —

Contract: furnishing and laying 18 888 ft. of pipe including rock excavation*	$206 690.32
Force account: materials and labor	14 084.81
Inspection	2 416.72
Overhead: printing, advertising, postage and miscellaneous	501.16
Total	$223 693.01

The new line was put into service on December 28, 1934. Since then, pumping has been continued through both the old and new mains.

In 1922, when the section of the new cast-iron main from the Pumping Station to Beaver Dam was completed, a cross-connection was made with the old steel main, and both mains were used to this point. The use of the two mains for this distance (approximately 12 000 ft.) resulted in a reduction of the friction head on the pumps amounting to 4 or 5 ft. when pumping at the rate of 10 m.g.d. When the entire line was completed and put into service in December, a further reduction of 6 ft. was noted.

No tests have yet been made to determine the relative friction head in the various types of pipe in the new line, but there is an excellent opportunity for such tests; also to compare the head in the new line and in the old steel main. We hope to make these tests when weather conditions are more suitable.

After the completion of the work comes the job of collecting the 30 per cent. grant from the Government. Twelve different blank forms (4 copies of each) filled out and signed by various officials, banks, etc., were submitted to the Federal accountant at Boston on January 26, 1935. I assume that they have been passed on to Washington and are now (March 21, 1935) either floating around the various Government departments or pigeonholed somewhere along the line. In any event, we have heard nothing from them, but are still hoping that they will come through in due time.

During the progress of the work the Government had a Resident Engineer Inspector constantly on the job. His clerical duties were so numerous, making daily, weekly and monthly reports to the Government, that his time actually spent inspecting the work was very limited. Numerous travelling inspectors showed up at irregular intervals whose principal

* Payment for rock excavation was on the basis of cost plus 15 per cent. 72 cu. yd. of rock were removed at a cost of $811.12, making the average cost $11.27 per cu. yd.

interest seemed to be confined to petty details such as pay of men, posting signs, hours worked and anything except the quality of work performed. This question was never raised by them. Two government auditors have spent many weeks making independent audits of bills, pay rolls, etc. in great detail. On March 15, a third accountant appeared to make a so-called supplementary audit which took several days.

On the whole, my impression of Public Works Administration is that it furnished a lot of unnecessary work for many people, but is entirely lacking in efficiency and economy.

It is very doubtful in my mind if the 30 per cent. grant allowed for labor and materials makes up for the extra cost and trouble caused by the many unreasonable regulations.

The design and manufacture of the pipe and the construction of the line are described by Colonel F. F. Longley in a paper in this JOURNAL. The chlorination of the line is similarly described by Mr. Ernest J. Sullivan.

MANUFACTURE AND CONSTRUCTION OF 48-INCH LOCK JOINT PIPE LINE, NEW BEDFORD, MASS.*

BY F. F. LONGLEY.†

[*Read March 21, 1935.*]

Mr. Taylor has set forth the history of this pipe-line project and the general conditions under which it was built. In the following, a description is given of the design and manufacture of the pipe and the construction of the pipe line.

The pipe line is a force main connecting the end of a 48-in. cast-iron pipe previously laid, with the city reservoir, and consists of approximately 19 000 ft. of 48-in. pipe. The conditions of operation indicated that steel-cylinder reinforced-concrete pipe was the correct type to use. This pipe consists essentially of a welded steel-cylinder having joint-rings welded to its ends; surrounded by a cage of reinforcing bars; and this entire steel structure encased inside and out in an envelope of dense concrete to form the finished pipe with a laying length of 12 ft. A typical section of this pipe is shown in Figure 1, in which the essential elements that have been referred to are all clearly indicated.

Constructing Steel Cylinders. In designing the pipe, a unit stress of 12 000 lb. per sq. in. was fixed as the limiting stress in the steel for normal operating conditions, and 20 000 lb. per sq. in. as the limiting stress for the assumed maximum surge conditions. The total cross-section of steel in the steel cylinder and in the surrounding steel cage was designed so that these stresses would not be exceeded.

The steel sheets for the cylinder arrived on the job from the mill in bundles of flat sheets. They were put through rolls to curve them to the proper radius and assembled into cylinders by means of temporary holding rings. Then the longitudinal seams were welded. The diameter of the steel cylinder was approximately 51 in., allowing a concrete lining of about 1½ in. to make pipe with a finished inside diameter of 48 in.

The joint rings, which were next welded upon the ends of the cylinder, are of the type which have been used by the Lock Joint Pipe Company in building the great majority of its pipe lines during the last decade or more. These rings are of galvanized steel and are designed to form a bell at one end of the pipe, and a spigot at the other. The cross-sections of these rings are so shaped that when the pipes are laid a wedge-shaped space is formed between the bell and spigot surfaces, into which a lead gasket is later

* See also preceding and following paper in this JOURNAL.

† Vice-President, Lock Joint Pipe Co., Ampere, N. J.

caulked. These joints are made by the Lock Joint Pipe Company at their shops in Ampere, N. J.

In the early days of the manufacture of these joint rings, the steel was put through rolls and the ends then welded together by hand welding to form a ring. Notwithstanding the utmost care in manufacture, the rings made in that way had certain defects which at times were troublesome. The present method of manufacture was therefore devised and completely eliminated the troubles found in the earlier rings. The ring stock is now cut to a length which is slightly less than the perimeter of the finished ring. It

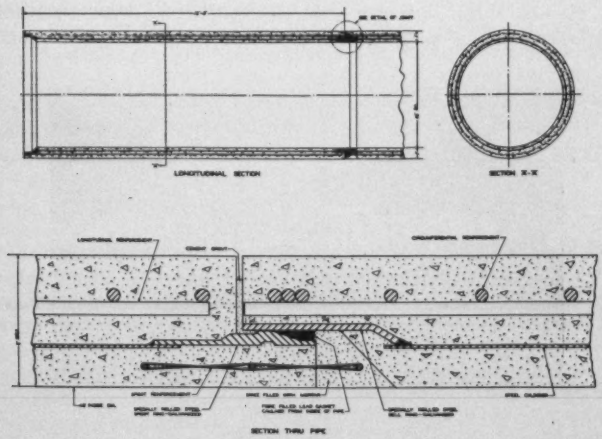

FIG. 1.—48-IN. REINFORCED CONCRETE STEEL-CYLINDER PIPE, NEW BEDFORD, MASS.

is put through rolls, and the ends are then welded together by means of an electric resistance welder, to form an endless ring. The ring, after this operation, is approximately a circle, but not a true circle. It is also somewhat smaller than the size required. The ring is then placed upon the table of a powerful stretching press to which a force can be applied sufficient to stretch the ring to the required size. In this operation of stretching, which can be very accurately controlled, the ring is given the exact diameter required and is formed into a perfect circle. At the same time, the weld is subjected to a severe strength test, namely, stretching it beyond the elastic limit of the steel.

It is worth remarking, in passing, that this method of manufacture of joint rings, together with the methods used in assembling the steel structure of the pipe, the joint rings and the moulds, and in holding them all in correct relative position during the operation of casting the concrete, produce a

very high degree of precision both as to dimension and to shape of the joint rings in the finished pipe, with the result that no pair of joints ever fails to go together in laying, notwithstanding the fact that the clearance between bell and spigot is less than $\frac{1}{16}$ in. No joint made by this process has ever been known to give trouble from leakage.

These joint rings are welded upon the ends of the steel cylinder under definite dimensional control. The usual position of the joint ring is, of course, at right angles to the axis of the pipe. To accommodate gentle curvature in the line, however, some pipes are made with the spigot rings set at a slight angle instead of exactly normal to the axis.

The cage of bars surrounding the steel cylinder was made by winding round steel rods on a spiraling machine to the diameter and pitch required

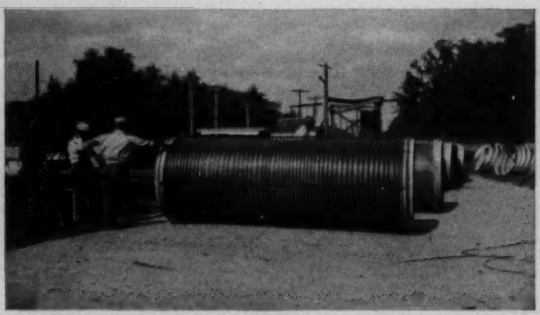

FIG. 2.— COMPLETE STEEL STRUCTURE READY TO BE CAST INTO THE CONCRETE.

by the design. The diameter of the cage was such that in the finished pipe there was at least an inch of concrete covering the steel at every point. The pitch depended upon the size of the bars and the cross-sectional area of steel required. This cage required some means of being held together as a unit. Longitudinal steel bars were used for this purpose and were fastened securely to the coils of the cage. Under some conditions, especially with reinforced-concrete pipe made without the steel cylinder, the longitudinals play an important part in giving the pipe beam-strength to resist transverse fracture. In steel-cylinder pipe, however, the cross-section of the steel of the cylinder itself is fairly large, giving great beam-strength to the pipe. Consequently the longitudinal bars of the cage of steel-cylinder pipe do not have to be designed primarily with respect to transverse strength of the pipe, but serve to assure a convenient degree of rigidity and security, so that the cage can be handled as a unit. The parts of the steel structure just described were then ready for assembly (see Fig. 2). At this point, however, the testing of its different parts should be mentioned.

Every part of the steel cylinder and reinforcement requiring test is tested in the course of fabrication. The testing of the joint rings has already been described, namely, a test of the weld at the elastic limit of the steel. The steel cylinders with the joint rings welded thereto were all tested for strength and watertightness, by internal water pressure. In the fabrication of the spiral cage, every weld in the circumferential steel bars was tested. Thus strength and watertightness were already adequately proved before the concrete of the pipe was cast around the steel.

As a convenience in the handling and assembling of the steel and the moulds, in preparation for casting the pipe, the spiral steel cage was slipped over the steel cylinder and fastened thereto by a welded connection which also served to hold the cage and cylinder at the proper distance apart, thus permitting the two to be lifted and handled by the crane as a single unit.

The foregoing all relates to the steel reinforcement of the pipe. The finished pipe, of course, has superficial surfaces of concrete, and anyone unfamiliar with the details of design may easily confuse the qualities of this kind of pipe with those of reinforced-concrete sewer pipe or culvert pipe. For water-works engineers considering types of pipe for pipe-line construction, it is important to keep in mind that steel-cylinder pipe, of the type built for the New Bedford job, is a totally different product from reinforced-concrete sewer pipe or culvert pipe. It is, in fact, essentially a steel structure containing all the required elements of strength and watertightness, and the concrete performs primarily the function of a protective covering for the steel. In addition, of course, the concrete also contributes the high compressive strength necessary to make the finished pipe safe to resist the stresses of external loading.

Pouring Concrete. Next came the operation of setting up the forms and the steel reinforcement in preparation for the pouring of the concrete. The mould consists essentially of four parts; the base ring, the inner casing, the outer casing, and the tamping platform. The base ring is a machined casting so shaped as to hold the inner and outer casings and the bell-joint ring correctly and rigidly in their proper and relative positions, and also to give the proper form to the concrete at the bell end of the pipe. This base ring is laid on the ground, and the inner casing is set upon it. The steel reinforcement of the pipe is then lifted by the crane and slipped down over the inner casing. The tamping platform is then placed upon the top. This tamping platform is of unique design and serves several different purposes, essentially to hold the inner and outer casings of the mould and the spigot ring of the pipe in correct, concentric position, and also to serve as a working platform and as a convenient means for spreading the concrete uniformly around the perimeter of the pipe inside and outside of the steel cylinder in the operation of pouring. The outer casing is then lifted by the crane and slid down over all. The casings are of course firmly closed by clamps. These several parts, when thus assembled, form a very rigid structure assuring highly precise dimensions and shapes in every pipe. (See Fig. 3.)

The materials for the concrete were selected with great care, rich, dense concrete being used for this pipe. The concrete was mixed at a batching plant installed for this job and was carried from the mixer to the forms in a large conical bucket with a special control gate which virtually assured a re-mixing of the concrete at the moment it was discharged from the

FIG. 3.— CASTING YARD, SHOWING FINISHED PIPE AND PIPE BEING CAST.

FIG. 4.— A SINGLE LENGTH OF PIPE VIEWED FROM THE BELL END.

bucket onto the tamping platform. The several moulds, constituting each day's pouring, were filled little by little and the concrete carefully consolidated as the filling progressed, resulting in a thoroughly filled mould, with pipe surfaces hard, dense and smooth.

The curing of the pipe was aided and controlled by the use of steam. The pipes of each day's casting were covered over and steam circulated around them. This produced an atmosphere moderately warm and satur-

ated with moisture. These conditions we have found favorable to a uniform and satisfactory curing. One of the purposes of using steam in curing is to assure a rate of setting, regardless of outside air temperature, which will unfailingly permit the removing of the moulds for use on the succeeding day, the performing of the other operations of finishing the pipe, and finally the lifting of the pipe from their bases and the turning and laying them on the skids, according to a regular and well established routine. With this requirement in view, it is obvious that the amount of steaming will vary with seasonal changes of temperature. The curing was thus varied in the manufacture of the New Bedford pipe, the principal governing consideration always being that the curing must proceed at such a rate that the concrete of the pipe will not be damaged in any of the operations which follow during the few days after the concrete is cast.

The well established routine which was followed on the New Bedford job, as on all other similar jobs, was to strip the inner and outer casings from the pipe the morning after the pipes were cast; then on the third day to lift the pipe off the base ring and to turn it on its side and place it in storage. This lifting of the pipe has in fact been done on some jobs on the evening of the second day after the pipe was cast. (See Fig. 4.)

The description thus far leaves us with the manufacture of the pipe completed and the pipe stored on skids in the manufacturing yard, and we now want to see how the pipe line was built. First let us look at the location of the pipe line.

Construction of Pipe Line. As Mr. Taylor has pointed out, the location of this new line parallels that of the old steel pipe line on the same right-of-way. The location is entirely rural. All of the wooded sections had previously been cleared. Some of the ground was high and some low and marshy. In certain places on this low ground the bottom of the pipe was shown at an elevation higher than the top of the original surface. This necessitated building some 2 000 ft. of suitable embankment to carry and protect the pipe.

As these low places became very wet and soft in rainy seasons, it was decided to build the embankment up to a point which would correspond approximately to the top elevation of the pipe, thus giving the best possible opportunity for a thorough consolidation of the underlying layers of fill. The surface was stripped down to firm ground for the width of the embankment and suitable filling material was hauled by trucks from borrow pits, deposited in layers, and compacted. Culverts under these embankments were built by the city of New Bedford.

The construction of the pipe line was commenced at High Hill Reservoir and progressed continuously the whole length of the line to the lower end at Braley's Station, using one laying-unit working two shifts per day. A full revolving Northwest back hoe excavator was used to dig the trench and also to lift, handle and place the sections of pipe in the trench. (See Fig. 5.) The pipes were hauled from the manufacturing yard to the ditch

on trucks. At the manufacturing yard a depressed road was built at the end of the skids in such a position that the pipe could be rolled directly off the skids onto the body of the truck.

The method of construction followed was to excavate enough trench for one 12-ft. length of pipe, to lay that pipe, and then to resume excavating for the next pipe. While some men were fitting the sling and preparing to lift the pipe, others were doing the final grading at the bottom of the trench to place the pipe at the proper line and grade. They were aided in this by the use of a large right-angle square which could be placed across the bell end of the last pipe laid with the long leg extended away from the bell end and

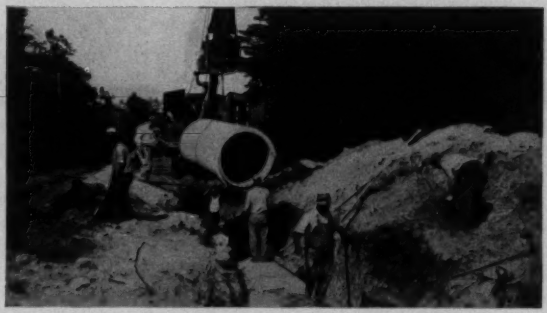

FIG. 5.—PIPE TRENCH WITH PIPE ABOUT TO BE LAID.

parallel to the axis of the pipe. The bottom of the trench was carefully trimmed and smoothed to this square in order to give as uniform a bearing for the pipe as possible.

While grading the trench, the inside surface of the bell ring of the last pipe laid was carefully cleaned and a coating of graphite grease applied. The wedge-shaped fibre-filled lead gasket was then placed snugly in position against the inside surface of the bell ring, and was sufficiently stiff to stay in place inside the bell. The pipe to be laid was then lifted by the crane, lowered into the trench and the steel ring forming the external surface of the spigot end of the pipe, after being cleaned and coated with graphite grease, was telescoped into the bell of the pipe previously laid. After the line and grade for this piece of pipe had been checked, with the pipe firmly on the bottom, the sling was withdrawn and the excavator moved into position to excavate for the next pipe.

Immediately after the pipe was thus laid, a strip of paper-covered burlap, about 8-in. wide, was wrapped tightly around the outside of the joint directly over the narrow space between the ends of the pipe. This burlap strip was for the purpose of keeping dirt from working into the joint,

pending the filling of the outside joint-space with mortar. The backfilling of the trench was then immediately commenced. The lower part of the trench was filled in layers and carefully compacted by hand-tamping up to at least as high as the spring line of the pipe. The remainder of the trench was then backfilled by machine. When backfilling reached approximately to the top of the pipe, the narrow open space on the outside of the joint between the bell and spigot ends of the pipe was filled with grout. It should be made clear that this grout filler has nothing whatever to do with the tightness of the pipe line, but that it merely serves the purpose of covering up the narrow line of galvanized steel of the joint ring which would otherwise be left in contact with the earth.

Immediately after each pipe was laid, the gasket lying inside the joint was given a preliminary caulking. This was done from the inside of the

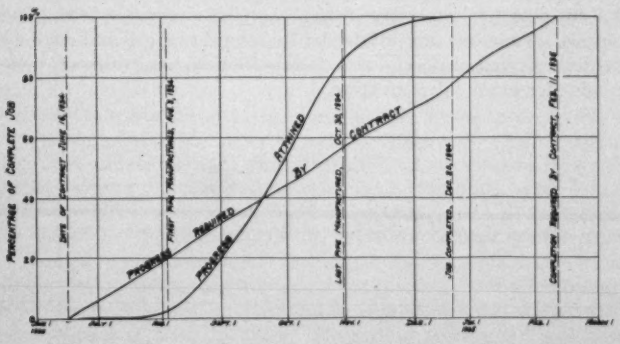

FIG. 6.— RATE OF CONSTRUCTION PROGRESS 48-IN. LOCK JOINT PIPE LINE, NEW BEDFORD, MASS.

pipe, an offset caulking tool and a fairly heavy sledge being used for the purpose. No effort was made in this preliminary caulking to secure complete watertightness in the joint. After this preliminary caulking, nothing was done to the joint until the trench had been entirely backfilled and the job as a whole was approaching completion. Thus as much time as possibe was allowed for the pipe and the backfill to settle as nearly as possible to its final position. Everyone knows that a pipe and its backfilling settle more or less, soon after the operation of laying. The methods followed in the sealing of the joint in this type of construction recognize this fact and are designed to attain watertightness *after* this settlement has taken place.

A few weeks before the construction job was completed a joint crew was sent into the pipe line, and the lead gaskets were given their final caulking. After each joint had been thus firmly and finally caulked in a manner to produce watertightness, the trapezoidal space lying between the

bell and spigot ends of the pipe in the inside surface was filled with cement mortar and smoothed off. This was the final operation in the construction of the pipe line, which was then ready for the acceptance test, regarding which Mr. Taylor has presented the facts.

The construction of this 19 000-ft., 48-in. pipe line was done well within the time required by the contract. Figure 6 shows the relation between the rate of progress required by the contract and the rate of progress which was actually attained.

It is a pleasure to note that Mr. Taylor intends to make tests to determine the friction in the three different kinds of pipe he now has in these main supply lines. We will await the results with confidence that the Lock Joint pipe line will again show the very high carrying capacity it has previously shown in tests made on numerous other lines.

Taking into consideration the substantial physical advantages of this Lock Joint pipe line, especially its high carrying capacity — both present and future, its excellent watertightness, its rugged strength and durability, and its well proved safety, the city of New Bedford has in this pipe line a large value for every dollar invested.

CHLORINATION OF 48-INCH PIPE LINE, NEW BEDFORD, MASS.*

BY ERNEST J. SULLIVAN.†

[*Read March 21, 1935.*]

The Water Department of the city of New Bedford chlorinated the 48-in. Lock Joint pipe line completed in December, 1934, before it was put into service. This pipe line extending from Braley's station, in the southeasterly part of the town of Freetown, to High Hill Reservoir, in the northeasterly part of the town of Dartmouth, is a part of the force main from Little Quittacas Pond to the high-service reservoir. The total length of the new line is 18 883 ft., or approximately 3.58 miles. Bulkheads made of heavy steel were placed at various points in the line for the purpose of testing the line in separate sections, and manholes similar to the type commonly used at the base of standpipes or riser columns on large elevated tanks were cast into the top of the pipe at certain strategic points. The bulkheads were placed on the reservoir or the southerly sides of these manholes. A 4-in. steel pipe extended through the bulkhead and was piped through the manhole on the pumping-station side of the bulkhead. This 4-in. pipe extended about 4 ft. above the top of the pipe in the form of an inverted U, each leg of the U terminating in the adjoining sections of the pipe line. A 4-in. gate valve was installed in the upright on the leg which extended into the section on the reservoir side of the bulkhead. A 1-in. coupling was welded into each leg and another into the top of the bend, and a valve was placed on each of these openings. This piping arrangement was installed primarily for testing purposes. The reason for this description of the installation is to give a better understanding of the methods used in chlorinating this pipe line. In three of the sections the chlorine was applied through one of the 1-in. openings.

It would seem fitting before discussing the chlorination of this pipe line to point out the possibilities of contamination during the construction. One should visualize a concrete cylinder 4 ft. in diameter and over 3½ miles long. The pipe was cast in 12 ft. lengths at Braley's Station, at the northerly end of the line, and was then hauled and placed in position in the trench. Every 12 ft. there was a joint. This had to be made up, caulked and grouted on the inside as well as the outside of the pipe after it was in place. A number of men were, therefore, constantly at work in the line. These men often stayed in the pipe for hours at a time. Under such conditions one does not need to stretch one's imagination to concede that there was a possibility of contaminating the pipe regardless of the care exercised by the

* See also the two preceding papers in this JOURNAL.

† Assistant Engineer, Massachusetts Department of Public Health, Boston, Mass.

officials and foremen. The pipe line was divided by bulkheads into six sections. The line was filled with water in five sections, the two sections nearest Braley's Station being filled as one.

The apparatus used in chlorination was an emergency chlorinator of the portable type, the maximum capacity being 42 lbs. of chlorine gas per 24 hours. This unit will inject chlorine either as a gas or as a solution in water. Because of inclement weather and danger of the apparatus freezing if the solution-feed method had been used, it was decided to inject the chlorine into the water as a gas by the direct-feed process.

On November 14, 1934 the section nearest High Hill Reservoir, which we may call the first section, was filled by gravity from the reservoir through a 36-in. pipe. This section was 1 109 ft. long and held 104 246 gal. of water. The chlorine was applied through a porous porcelain diffuser inserted into the pipe through a manhole located about 150 ft. north of the gate valve. The dosage was 9 p.p.m. of chlorine. It was difficult to keep the diffuser submerged because of the steep grade in this section of the line, and because of the velocity of the water as it passed the point of application. It took about two hours to fill this section. A test was made for residual, or free, chlorine at the end of the first hour of chlorination and showed 2 p.p.m. Another test for free chlorine was made at the end of two hours with the same result. After the water had been standing in the pipe 24 hours, 0.75 p.p.m. of free chlorine was present. A sample of the water was collected for bacterial examination 24 hours after treatment.

The second section north of the reservoir, 2 407 ft. in length and holding 226,258 gal., was filled by gravity from the reservoir through the first section by the piping arrangement previously described. Approximately one-half of the water used in filling this section had therefore been prechlorinated. The chlorine was applied through the 1-in. opening on the inlet leg of the U, but this point of application did not prove altogether satisfactory because air became trapped in the pipe line and had to be released through the opening at the top of the U. To do this the water had to be shut off and the chlorinator shut down to free the line of air. The dosage applied on this section was practically the same as in the first section, namely 10 p.p.m. A residual of 2 p.p.m. of free chlorine was obtained after one hour of contact, a residual of 0.5 p.p.m. after 24 hours, and a residual of 0.2 p.p.m. after 48 hours. A sample of water for bacterial examination was collected also from this section 24 hours after treatment.

The third section north of the reservoir, 2 403 ft. in length and holding 225 882 gal. was also filled by gravity from the reservoir through the sections already sterilized. The dosage and procedure in sterilizing this section was practically the same as in the second section except that the chlorine was applied in the outlet leg instead of the inlet leg. A sample of this water tested 24 hours after chlorination showed 2 p.p.m. of free chlorine and after 48 hours, 0.2 p.p.m. All of the water used in filling this section had been prechlorinated.

For the fourth section north of the reservoir, 4 976 ft. long and holding 467 744 gal., the method used in filling and sterilizing was the same as in the preceding section. After 24 hours of contact this water showed a free-chlorine content of 3 p.p.m. and after 72 hours 0.15 p.p.m. Approximately one-half of the water used in filling this section was pre-chlorinated.

The last section was filled and sterilized on December 6, 1934. This section is 7 988 ft. or slightly more than 1½ miles long and holds 750 872 gal. The water was pumped into this section through the 48-in. cast-iron force main which extends from the northerly end of the newly constructed Lock Joint pipe to the pumping station located on the southerly shore of Little Quittacas Pond. Chlorine was introduced into the water entering the new line at a point about 750 ft. north of the end of the new pipe line. The water was treated with 10 p.p.m. of chlorine. The point of chlorine application was very important due to the fact that the weather was cold, the pressure of the gas in the chlorine tank was low, and it was impossible to inject chlorine into the water after a certain head had been built up in the pipe line. Solution feed was impracticable due to the danger of the water lines

Section No.	Contact Period-Hours.	Bacteria per Cubic Centimeter.			B. Coli in				
		4 Days 20 C.	24 Hours—37 C.		0.01 cc.	0.1 cc.	1 cc.	Five 10 cc. Samples	
			Total.	Red.				Pos.	Neg.
1	24	6	2	0	0	0	0	0	5
2	24	1	0	0	0	0	0	0	5
3	24	3	2	0	0	0	0	0	5
4	24	2	4	1	0	0	0	0	5
4	72	3	1	0	0	0	0	0	5
5	8	5	0	0	0	0	0	0	5

freezing as the work was carried out in the open with little or no shelter. Under the circumstances the best solution seemed to be to choose a point lying beyond the end of the pipe line to be chlorinated by a distance equal to that which had to be filled after the pressure became too great to inject chlorine into the water. The grade of the cast-iron line beyond the end of the new line was slight in comparison with the grade of the southerly or most distant end of the section being chlorinated. Therefore, selection of a point 750 ft. beyond the end of the section permitted displacing chlorinated water from the cast-iron pipe line into the section to be chlorinated.

The results of the bacterial examinations of the samples of water collected from each section after chlorination are given in the schedule above.

The effectiveness of chlorination with 10 p.p.m. of chlorine, about half of the amount recommended by some authorities for cast-iron pipe, is apparent. In conclusion it might be pointed out that in all but one of the

sections a residual of at least 2 p.p.m. was obtained after 24 hours of contact and in one instance a residual of over 0.10 p.p.m. after 72 hours. The pipe line was flushed out thoroughly before being placed in service.

By chlorinating this main the officials of the New Bedford Water Department eliminated the possibility contaminating the water supply of the city from this source.

PROCEEDINGS.

JANUARY, 1935, MEETING.

HOTEL STATLER, BOSTON, MASS.

Thursday, January 17, 1935.

President Howard M. King in the Chair.

Secretary Gifford announced the election by the Executive Committee of the following new members:

James A. Sweeney, Construction Superintendent, Manchester, N. H.
James P. Curtiss, Operator of Filter Plant, Simsbury, Conn.

ARTHUR C. KING* presented a proposed Massachusetts bill for discussion. The bill follows:

Sec. 1. In cities or towns whose charters provide for the duties of water commissioners to be exercised by some certain other officer or board, the provisions of this act shall be applicable to such officer or board and the words "Water Commissioners" shall be understood to mean such officer or board.

Sec. 2. The Water Commissioners shall have full charge, control, and management of the water works.

Sec. 3a. All water department revenue shall be held and appropriated only for maintenance, operation and improvement of water works plants, for the retirement of water works bonds, and for the payments of interest upon such bonds.

Sec. 3b. All water departments, as an operating expense, may, when voted by the town, pay to the owning municipality a sum of money in lieu of taxes based on plant values, but not to exceed 3 per cent. of said value. All municipalities shall pay their water departments fair annual charges for fire protection, and all municipalities shall pay their water departments for water used for other municipal purposes at the rates charged to other consumers, which rates, including the charge for fire protection, shall be sufficient to meet the operation costs of the department. In fixing the sum to be paid in lieu of taxes, and the charge for fire protection, the same basis of plant valuations shall be used, and for this purpose the water departments shall carry in their annual reports a statement of said plant values. Should any questions arise as to the unreasonableness of the sums charged in lieu of taxes, or as to the charges for fire protection, appeal may be made to the Department of Public Utilities, whose decision in the premises shall be final.

MR HAROLD SHERMAN GOLDBERG spoke on behalf of the Boston Emergency Campaign.

ARTHUR C. RUGE, Research Associate in Seismology, Massachusetts Institute of Technology, gave a talk on "Earthquakes: The Possibility of their becoming a Problem in New England and Their Effect on Elevated Water Tanks." The talk was illustrated by lantern slides, and a model tank and a building on a "shaking table" to simulate the action of an earthquake. An Edgerton stroboscope was used to slow down the motion of the model. A summary of Mr. Ruge's talk appears below.

L. F. JACKSON of the Linde Air Products Company, Boston, gave a talk on the "Lindeweld Process for Pipe Line Construction," and showed motion pictures. [*Adjourned*]

* Taunton, Mass.

Earthquakes: The Possibility of Their Becoming a Problem in New England and Their Effect Upon Elevated Tank Structures.

[Summary of a talk presented by Arthur C. Ruge, Research Associate in Seismology, Massachusetts Institute of Technology, on January 17, 1935.]

Before describing his own researches at the Massachusetts Institute of Technology, Mr. Ruge discussed briefly the earthquake history of this vicinity and pointed to the possibility of infrequent but severe future quakes. Few New Englanders know that their section of the country has been visited many times by earthquake; in at least three instances since the white settlers arrived the quaking was quite severe. The following table lists the important historic earthquakes in New England and their comparative intensities:

1638. Plymouth, Mass. Very strong. Many chimneys thrown down.
1663. New England. Severe. Destruction mainly limited to chimneys.
1727. Newbury, Mass., to Cape Cod and Nantucket. Much cracking of brick houses — chimneys thrown down.
1755. Boston and vicinity. Most severe on record. More than 1200 chimneys fell. Gable ends of 12 or 15 buildings torn down to the eaves.
1925. Most recent one felt in New England States — originating in St. Lawrence Valley. Classed as "weak" in New England but felt by most persons.

Many other quakes have been felt in New England and several earlier ones were described by the Indians to the settlers, but the first four listed above are the important ones from the engineering standpoint.

Attention was drawn to the fact that Boston presents an entirely different earthquake aspect from that up to and including the 1755 quake. At that time Boston was a relatively small city built on solid natural land; besides, there were no tall structures in existence. Modern Boston, however, is built to a large extent on filled or "made" land — a condition generally believed to increase the earthquake hazard considerably. In addition, we now have many tall structures which might suffer damage from a quake such as that of 1755. The speaker said that he believed a repetition of that quake in Boston might quite conceivably produce a disaster of major importance today.

Opinions are divergent as to the significance of the long period of freedom from violent shaking, some authorities holding that it indicates the end of New England seismic activity; while others believe that the 180 years of relative quiet are to be viewed with some apprehension since it may mean that strains in the earth's crust have been gradually accumulating which must some day be relieved by a violent quake. The speaker was emphatic in stating that, with present knowledge, no one can make a reliable prediction, nor is it likely that earthquake prediction will ever become a science exact enough to be very useful to the general public. He gave as his own opinion, however, that sound engineering judgment should recognize the

possibility of future quakes in this region, and, where economically possible, take some account of it in design and choice of location without becoming alarmed about the situation. Expressed in another way, it would appear that it is more logical to spend extra money on such improvements to public safety as fire protection, disease prevention, etc., which promise certain returns, than to invest it in attempting to ward off a very problematical eventuality. If money for both should be available, the earthquake hazard might well be considered.

Certain precautionary measures, however, can and should be taken in any locality which has reason to expect earthquakes. These are measures which do not affect the economics of the undertakings, but still can be of great value to the community in the event of a disaster. Important water supplies should not be stored on "made" or filled land; or, if this condition cannot be satisfied, special attention should be given to the foundation design. Gas and electric companies should have safety plans definitely worked out to meet the emergency of a serious quake. The water supply for fire fighting should be studied and plans made to cope with various situations which may be expected to arise as a result of earthquake action. The most important feature of such plans is the definition and allocation of duties to the proper persons — the confusion due to a lack of previous consideration of what to do has been very costly at times, while, on the other hand, quick action in applying predetermined safety measures has prevented the loss of vast sums of money in the form of property damage and has perhaps saved many lives as well.

The remainder of the talk was devoted to a study of the effects of earthquakes on elevated water tanks. Laboratory studies made at M. I. T., using a model tank shaken by miniature earthquakes, were described and illustrated by slides. Several typical tank failures in the Long Beach, Cal., quake of 1933 were shown. A model of a water tank and of a three-story building frame were shaken on a portable "shaking table" to illustrate the characteristic behavior of such structures when acted upon by earthquakes. An Edgerton stroboscope was used to make the motions easily observed by the unaided eye.

Mr. Ruge has concluded from his studies and experiments that the usual methods of quake-resistant tank tower design are not at all rational and that they often add greatly to the cost of the structure without providing any beneficial effects. Indeed, he stated that, paradoxically enough, moderate reinforcing of a given tower structure may even lower its earthquake resistance. New England water works engineers were advised not to spend money reinforcing their water tank towers against quakes — at least not until a satisfactory and economical solution to the problem is found. Research on the subject is still in progress at M. I. T., and the speaker expressed the belief that before many months have passed he will be able to announce such a solution. This research project is being sponsored by the Associated Factory Mutual Fire Insurance Companies and the Freeman Engineering Company.

FEBRUARY, 1935, MEETING.

HOTEL STATLER, BOSTON, MASS.

Thursday, February 28, 1935.

President Howard M. King in the Chair.

Secretary GIFFORD announced the election by the Executive Committee meeting of the following new members:

Members: Philip J. Holton, Jr., Superintendent, Scituate Reservoir Division, Providence, R. I.; Howard P. Shattuck, Superintendent Water Department, Winthrop, Mass.; Henry Wiesner, Jr., Water Works Engineer, North Eastern Water & Electric Service Corp., Millbury, Mass.

Corporate Members: Newburyport Board of Water Commissioners, Newburyport, Mass.; Norwich Board of Water Commissioners, Norwich, Conn.

Secretary GIFFORD discussed certain legislative measures pending before the Massachusetts Legislature.

It was duly moved and seconded that a letter protesting against the passage of House Bill No. 526 on behalf of the Massachusetts members of the NEW ENGLAND WATER WORKS ASSOCIATION be sent, and in the event that another hearing is held that personal appearance before the committee be made and opposition offered to the bill.

[The question being put, was unanimously adopted.]

A. C. KING.* Relative to Bill No. 1737 requiring the licensing of persons having charge of or operating internal combustion or Diesel engines, I move that the Massachusetts members go on record as being opposed to that bill.

This motion was seconded, and the question being taken, the motion was unanimously agreed to.

E. SHERMAN CHASE.† At the Executive Committee meeting this morning the following resolution was approved and I wish to present it as a motion:

Whereas there has been an increasing tendency in recent times to inject partisan politics into the management of water works and

Whereas the tenure of office of experienced and capable water works' superintendents and employees is being menaced by political interference, and

Whereas the health and comfort of the public depend in no small measure upon the expert operation of water works systems by competent men,

Be it resolved that the NEW ENGLAND WATER WORKS ASSOCIATION hereby records its strong disapproval of political interference with water works operation, and

Be it further resolved that the NEW ENGLAND WATER WORKS ASSOCIATION records its equally strong approval of tenure of office of water works departments and dismissal therefrom only for good and adequate cause.

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*Taunton, Mass. † Of Metcalf and Eddy.

This motion was duly seconded, and the question being taken, the motion was agreed to.

A paper "Seepage through Dams," was presented by Arthur Casagrande, Assistant Professor of Soil Mechanics, Harvard Graduate School of Engineering, Cambridge, Mass.

A paper "Welded Steel Pipe for Water Supply Purposes," was read by V. P. Marran, Vice-President, Walsh Holyoke Steam Boiler Works, Inc., Holyoke, Mass.

The paper was discussed by Caleb M. Saville, Patrick Gear, and A. O. Doane.

[*Adjourned.*]

March, 1935, Meeting

Hotel Statler, Boston, Mass.

Thursday, March 21, 1935.

President Howard M. King in the Chair.

Secretary Gifford read the report of the Finance Committee and it was accepted.

A paper "Pumping Water — an Historical Review," was read by Walton H. Sears, Mechanical Engineer, Metropolitan Water District, Water Supply Commission, Boston.

A paper "Summary of Old Steel Line; Necessity for New One; Progress in Earlier Stages of New Force Main; Summary of Work Completed," was read by Stephen H. Taylor, Superintendent, New Bedford Water Department, New Bedford, Mass.

A paper "48-in. Lock Joint Pipe Line for New Bedford Water Works," was read by Colonel Francis F. Longley, Vice-President, Lock Joint Pipe Company, Ampere, N. J. This paper was discussed by William W. Brush.

A paper "Chlorination of New Pipe Line after Completion," was read by Ernest J. Sullivan, Sanitary Engineer, Massachusetts State Department of Health, Boston, Mass. This paper was discussed by William W. Brush.

[*Adjourned.*]

SPRING MEETING, 1935.

MOHICAN HOTEL, NEW LONDON, CONN.

Thursday, May 16, 1935.

President Howard M. King in the Chair.

Mayor Cornelius D. Twomey welcomed the ASSOCIATION to New London.

Secretary GIFFORD announced the election of the following new members:

Members: William R. Sanford, North Providence, R. I.; Walter H. Chase, Mystic, Conn.; Harold Fox, Boston, Mass.; Clinton Inglee, Amityville, N. Y.; Charles H. Tompkins, Somerset, Mass.; Robert P. Trask, Lexington, Mass.; Harold S. Woods, Portsmouth, N. H.; Paul Pazziani, Director of Water Service, Geneva, Switzerland.

A paper "Water Rates" was read by Colonel Edwy L. Taylor, Chairman, Connecticut Public Utilities Commission.

A paper "Fire Service Charges," was read by H. E. Halpin, Engineer, Associated Factory Mutual Fire Insurance Companies.

A paper "How to Make Cross Connection Surveys," was read by Warren J. Scott, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health.

The discussion of these three papers was participated in by Charles L. Pool, Frank J. Gifford, A. L. Pierce, Percy A. Shaw, E. Sherman Chase, Arthur L. Shaw, Henry T. Gidley, L. K. Sherman, Samuel H. MacKenzie, Robert Spurr Weston, William A. MacKenzie, George E. Watters, Roger W. Esty, and Victor Bengle.

[*Adjourned.*]

REPORT OF COMMITTEE ON EDUCATION.

The following is the report of the Committee on Education regarding the Water Works School which was held at Portland, Maine, with the coöperation of the Portland Water District, April 2–4, 1935.

The school was held at the shops of the Portland Water District, where every convenience was placed at the disposal of the Committee.

The teachers were as follows:

Professor George E. Russell, Massachusetts Institute of Technology.
Mr. Harry U. Fuller, Portland Water District.
Professor Gordon M. Fair, Harvard Graduate School of Engineering.
Professor George M. Graffan, Portland University.
Mr. C. L. Ward, Portland Water District.
Mr. Milton Thorne, Portland Water District.
Professor Melville C. Whipple, Harvard Graduate School of Engineering.
Mr. Harold Scales, Portland Water District.

In addition, the Chairman gave a talk on "Modern Methods of Water Purification" following the dinner which ended the sessions of the school on April 4.

Messrs. Fuller, Ward, Graffan, Thorne and Scales were both instructors and attendants at the school.

The following twenty-two men attended the school:

Percy H. Belyea	Portland Water District
Clarence P. Renell	Portland Water District
Roy B. Hill	Portland Water District
Everett O. Boothby	Portland Water District
Erwin B. Ryder	Portland Water District
Thomas A. Meunier, Supt.	Sanford, Maine
Leavitt R. Smith	Portland Water District
Maurice A. Libby, Acting Supt.	Bath, Maine
Charles R. Moore	Portland Water District
Charles H. Pattengall	Portland Water District
George S. Wescott	Portland Water District
Elmer E. Jameson, Supt.	Friendship, Maine
Lyndall K. Parker, Supt.	Auburn, Maine
C. L. Ward	Portland Water District
Harry U. Fuller	Portland Water District
George M. Graffan	Portland Water District
Milton Thorne	Portland Water District
Harold Scales	Portland Water District
Harold Brigham, Supt.	Marlboro
James H. Lucas, Supt.	York
Charles M. Hobbs, Supt.	Farmington
J. Arthur Jackson	Portland Water District

The dinner at the close of the school was furnished by the Portland Water District, and was attended also by various employees of the District who had not attended the school.

On April 5, the day following, a party inspected the supply works of the District at Lake Sebago.

The Committee recommends that the Association extend its formal thanks to the Portland Water District, and particularly to David E. Moulton, Esquire, Clerk and Attorney; Mr. F. J. Reny, Treasurer; and Mr. Harry U. Fuller, Chief Engineer, for their successful planning and coöperation in the interests of the school.

R. S. WESTON,
Chairman, Committee on Education.

RECENT CHANGES IN ADDRESS.

BLACK, Ernest B.
Formerly: Mutual Bldg., Kansas City, Mo.
Now: 4706 Broadway Blvd., Kansas City, Mo.

CLARK, ARTHUR T.
Formerly: Troy, N. Y.
Now: Manager, Morristown Water Dept., Morristown, N. J.

DWYER, JOHN D., Chairman, Medford Water and Sewer Board.
Formerly: 228 Spring St., Medford, Mass.
Now: 110 South Border Rd., Medford, Mass.

EDWARDS, WILLIAM R., Vice-President and General Manager, Water Service Corp.
Formerly: 27 William St., New York, N. Y.
Now: 722 Reynolds Arcade, Rochester, N. Y.

KNOX, STUART K., Hydraulic and Sanitary Engineer.
Formerly: Partner, Nicholas S. Hill, Jr., New York, N. Y.
Now: 11 Broadway, New York, N. Y.

STEPHENSON, FRANK H., Engineer.
Formerly: 10 No. Fulton Ave., Mt. Vernon, N. Y.
Now: 730 E. 35th St., Brooklyn, N. Y.

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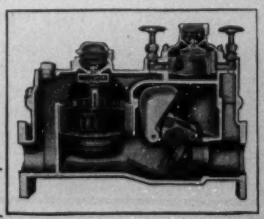

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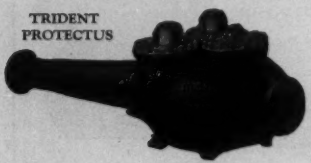

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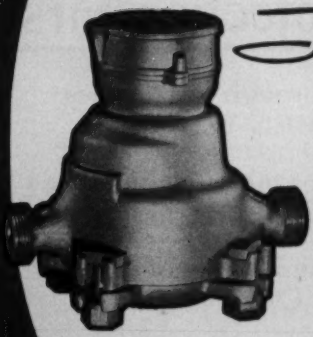

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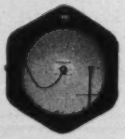

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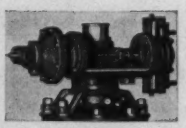

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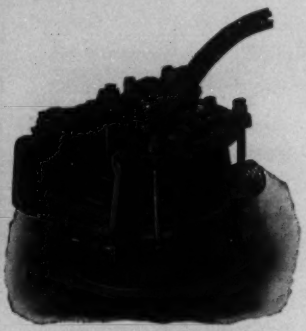

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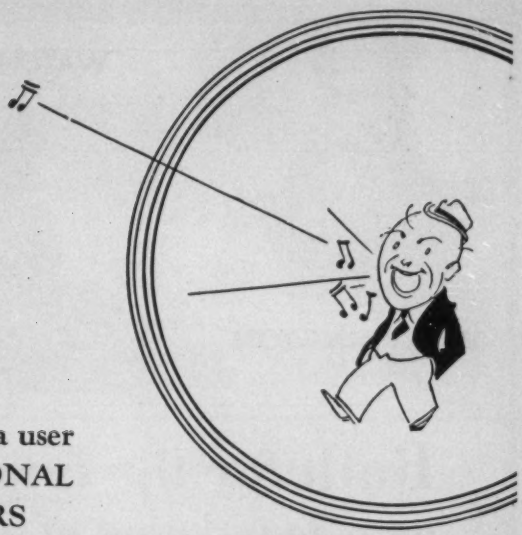

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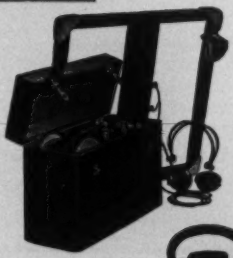
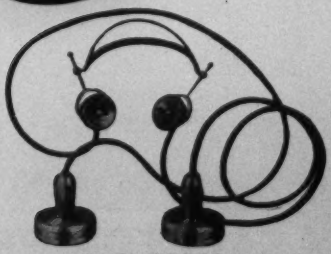


"AQUAPHONE"



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DUTCH BOY WHITE LEAD & RED LEAD

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FOR CAST-IRON PIPE
FOR COLD WATER METERS

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Minimum Trouble and Expense When Breaks Come

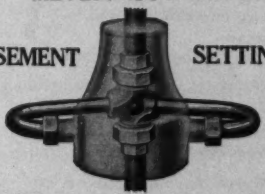
THE Smith Two-Part Standpipe Hydrant was designed to make the expense as small as possible when there is a break as the result, for instance, of careless auto truck driving.

The upper section will always break first. It can easily be renewed. And of course there can be no leakage of water because the main valve is of the compression type.

SMITH
2-Part Standpipe Hydrant

THE A. P. SMITH MFG. COMPANY
EAST ORANGE, N. J.

The
COPPERHORN
METER COUPLING
for BASEMENT SETTINGS



- ●1 Meter set horizontally at desired height in vertical pipe without ells, nipples or couplings.
- ●2 All copper water way. No rusting or corrosion. Freezing will not burst it.
- ●3 Smooth oversize tubing and sweeping bends, maximum flow.
- ●4 Meter changes do not disturb piping whether the meter is in or out.
- ●5 On new services it serves as a spacer to connect in the piping.
- ●6 Provides a permanent electrical ground connection.

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The FORD METER BOX COMPANY
Wabash, Indiana

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with the

Hays Copper Service Method

The Hays method of joining copper pipe has made it the choice of hundreds of far-sighted water works officials. The Hays Copper Service Method covers every underground service requirement, it makes copper "talk" in any good pair of hands.

Once a Hays Connection is laid and buried it stays down, not for 5, 10 or 15 years, but for generations. 99 9/10% pure copper in heavy wall tubing and the patented Hays connection can take any punishment that settling soil, vibration, twist, or pull can give. It's a permanent method that puts service replacement costs on the toboggan.

If Water Depts. require Radius Seal Connections for Copper Service, Hays is equipped to take care of their needs.

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HAYS MFG. CO.

ERIE, PA.

Fig. 108E

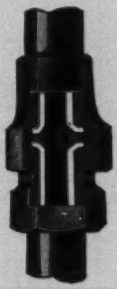


Fig. 120S

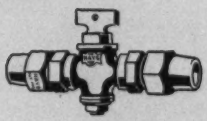
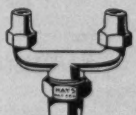


Fig. 54E

Fig. 119E



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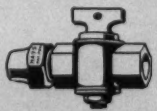

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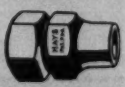

Fig. 121A

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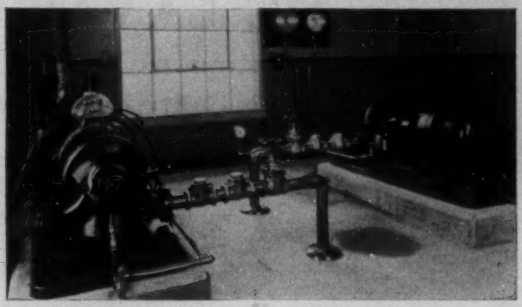

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Wherever water service departments investigate — go into a thorough analysis of pump construction — "5810" wins! For this pump has a long list of exclusive features which are sure to appeal to the man who knows pumps.

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Automatic Continuous Vacuum Priming System for Centrifugal Pumps

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WALLACE & TIERNAN CO., Inc.

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NEWARK, NEW JERSEY Branches in Principal Cities...Main Factory, Belleville, N. J.

56-39

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Now, Golden-Anderson offers you the supreme development in the Thru-Flow or Cone type Valves.

In the new Golden-Anderson Thru-Flow Valve the plug is unseated axially, rotated, and reseated axially, all in one free and frictionless operating movement and drop tight in either open or closed position; this is accomplished by means of a simple and sturdy patented toggle type rotor mechanism which is encased in a bath of oil in the operating head.

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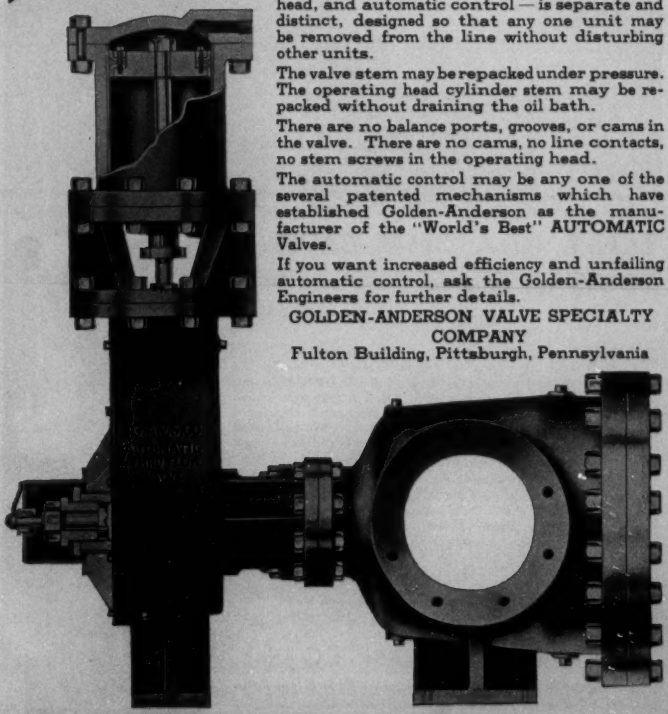
Fulton Building, Pittsburgh, Pennsylvania



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Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

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Will not flood if broken.

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New England Water Works Association

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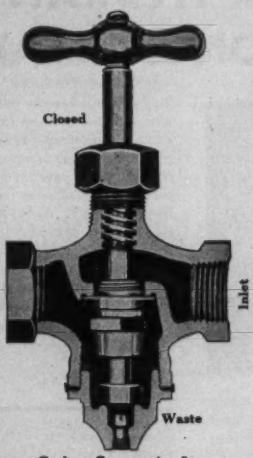
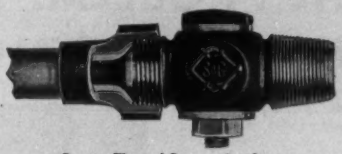


Gorham Compression Stop and Waste Cock



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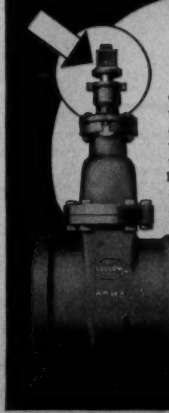

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Saves Money
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Troy, N. Y.

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It would seem an easy job to pick any hydrant to operate so seldom. But such a hydrant is not easy to find because it's not easy to make. If it were in use every day you'd know it was working. It would keep itself supple, clear of rust, free. But look what happens to a hydrant:

You install it, inspect it, and try the pressure. It works fine. Then you go away and leave it. This afternoon it rains, tonight it freezes. Tomorrow the sun shines hot. In winter it's zero. In summer it hits

a hundred . . . That piece of iron and bronze and leather has to stand motionless through it all. Meanwhile water, which may be corrosive, pushes at its base. Frost, which may go down three feet, heaves at its joints. And perhaps a careless truck takes a smack at its head. This goes on for months and years... Then firemen arrive on the run. Will its valve open instantly and wide? Will its water flow at full high pressure? Will it turn off completely and then drain immediately? That's the problem. And because it's your problem, we at R. D. Wood Company made it our problem 65 years ago when we started making Mathews Hydrants. It's been our problem, and our pride, ever since... The Mathews Modernized Hydrant, as made today, has no point where iron moves on iron. Bronze mountings prevent rust-tightness. It is so constructed that water is permanently sealed away from its operating threads. It is protected simply but thoroughly against ice on the working parts, ice in the standpipe, and the thrust of frozen ground.

The Mathews protection-case construction is doubly strong against traffic accidents and it is not weakened by any theoretical breaking point. But, since no construction could invariably prevent breakage, it is so built that if smashed at any point, the piece can be unscrewed and replaced by a new barrel in a few minutes.

Many Mathews Hydrants today have served more than 60 years and still function as often or as seldom as they are asked to. We believe that your best once-a-year equipment, your best fire protection, is

MATHEWS HYDRANTS

and "SAND-SPUN" PIPE, a superior grade, centrifugally cast in sand moulds.

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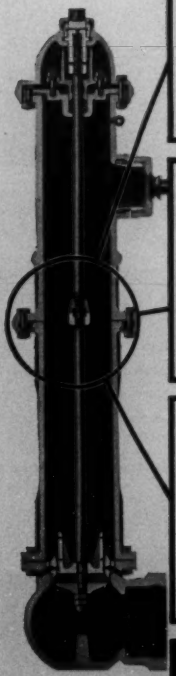
We call it a "Safety Flange"

--but "safety" is only part of the story--



LENGTHENING

Remove safety flange and coupling and add section as shown. No water cut-off; no digging.

SWIVELING

Loosen eight bolts that hold safety flange and swivel hydrant to any degree of circle. No digging; no water cut-off.

CHANGING NOZZLES

Safety flange offers convenient way of changing barrel section to one with hose and steamer nozzles. No water cut-off; no digging.

OF COURSE the primary purpose of the safety flange of the Columbian Fire Hydrant is to confine breakage by trucks or automobiles to a few inexpensive parts. But do not overlook the fact that it also offers three other important advantages:

(1) An inexpensive way of lengthening the hydrant to conform to new grade levels.

(2) A simple means of swiveling the barrel so that the nozzles can be faced to any degree of a circle.

(3) A simple, quick way of adding steamer connections to hydrants as conditions call for steamer nozzles.

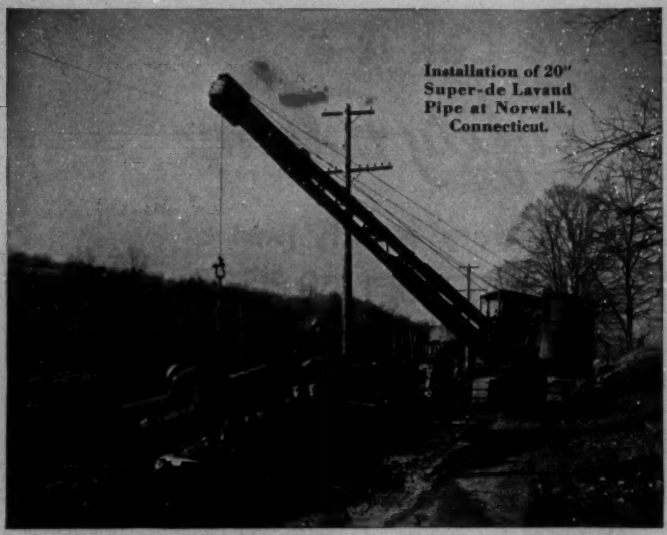
All of these changes are made, as illustrated, without digging, without cutting off water, and at minimum cost. Cities grow, grade levels change; conditions change. Therefore even if the greater feature of protecting vital parts were forgotten, these three features of lengthening, swiveling and changing connections would make Columbians a sound investment.

In addition, Columbian offers many other features found in no other hydrant. Write today for detailed description of your *future* fire hydrant.

COLUMBIAN IRON WORKS
CHATTANOOGA, TENNESSEE
Division of MUELLER COMPANY
DECATUR, ILLINOIS

COLUMBIAN

FIRE HYDRANTS AND GATE VALVES



Installation of 20" Super-de Lavaud Pipe at Norwalk, Connecticut.

IMPACT RESISTANCE DOUBLED

Double strength to resist impact shocks means that Super-de Lavaud Pipe offers these plus-values: super-service underground—and maximum protection from plant to underground. Two years ago that statement was based on exhaustive tests. Today it is confirmed by the experience of purchasers who have installed nearly *eight million feet.* Super-de Lavaud Pipe is the result of a patented process amounting to a basic discovery whereby gray iron is *centrifugally cast against metal without chill.* Ductility and toughness are increased, and impact resistance *more than doubled,* without reduction of tensile and bursting strength.

We shall be glad to send you a booklet describing the Super-de Lavaud Process.

U.S. SUPER-de LAVAUD PIPE

CAST WITHOUT CHILL IN A METAL MOLD

UNITED STATES PIPE AND FOUNDRY CO. General Offices: BURLINGTON, N. J.

Foundries and Sales Offices throughout the United States

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness. ALL MEMBERS OF THE ASSOCIATION RECEIVE THE JOURNAL IN PART RETURN FOR THEIR ANNUAL DUES; to all others the subscription is four dollars per annum.

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LEADITE

Regarding that "OR EQUAL" phrase

Many specifications and bidding-forms refer to (something definite),— "OR EQUAL," etc.

Now, in many cases, THAT "CLAUSE" is unquestionably fitting and altogether proper,— particularly where there are several products (or devices) of similar quality and merit, which might be considered for the desired use.

However, where long experimentation and actual service experience have "definitely proven" that one product possesses characteristics and advantages not common to so-called "EQUAL" or similar products, it seems to be questionable whether these products should be classified or specified as "equals" (even though they are manufactured to be used for the same purpose).

Of course,— someone might suggest, that in these progressive days, there is NO ONE PRODUCT vastly superior in quality, characteristics and advantages, to its competitive products. However, the best answers to this are: (1) What results has the product given over a period of years in service? (2) Who uses the product, and "why" do they use it? (3) How long has the product been used? (4) What do the users think of the product?

Another point,— is the "PRICE" OF THE PRODUCT. After all, one can safely say that "ONE ONLY GETS WHAT ONE PAYS FOR,"— and as a nationally known motor car maker used to advertise,— it's a question of "WHAT COMES AFTER THE PURCHASE PRICE?"

In conclusion,— we feel that the "OR EQUAL CLAUSE" in specification and bidding forms, should mean EXACTLY WHAT IT IMPLIES, i.e.: EQUAL IN EVERY WORTHWHILE RESPECT TO THE PRODUCT WITH WHICH IT IS COMPARED. One can purchase almost anything represented to be "just as good," at a lower price,— but, IS IT JUST AS GOOD IN EVERY WORTH WHILE RESPECT? THAT, seems to be the problem for progressive and careful purchasers to seriously consider.

The pioneer self-caulking material for c. i. pipe.
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Saves at least 75%

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Girard Trust Company Bldg. Philadelphia, Pa.

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